ERGONOMIC DEMANDS IN AUTOMOTIVE COMPONENT INSPECTION TASKS

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Abstract: Investigations revealed poor ergonomic design, unsatisfactory logistics and quality problems at assembly and inspection workplaces in a large corporation supplying fenders to the automotive industry. A 138-item job design checklist was used to assess 59 reference workplaces. The design profiles highlighted weak points, especially as regards anthropometry and movement sequences. Ergonomically optimized assembly and inspection workplaces compatible with production flow were designed and introduced. Productivity improvement groups were created and action was taken to encourage good ergonomic behavior. The job contents were enlarged.

1. INTRODUCTION

ISO 9000 and the more stringent requirements now being imposed by automotive manufacturers are combining to make quality control exceptionally important for companies supplying components to the automotive industry. Optimal ergonomic design of work systems is consequently one of the factors contributing to the business success of an automotive component supplier. Other key factors are the selection and training of the “right” persons to perform the inspection tests.

This contribution is a report on a project for analysis, evaluation and redesign of painting, assembly and inspection jobs in five production plants of one of Europe’s largest suppliers of fenders to the automotive industry. The poor quality and low efficiency of the work being performed were serious enough to endanger survival of these production plants. It was planned to use the study results to develop a job design strategy involving changes in workplace ergonomics, work sequences and job logistics that would be introduced, as far as possible, in accordance with a coordinated plan throughout the whole of the corporation’s manufacturing operation.

2. METHODS

Following tours of inspection of the five production plants together with industrial engineers working there, 59 ergonomically representative workplaces were selected and subjected to ergonomic diagnosis. The checklist designed by Landau und Bokranz (1986) and based on the AET Job Analysis Technique (Landau und Rohmert 1989) was used to identify deficits in workplace design. This checklist has already proved its worth elsewhere in the automotive industry. It is subdivided into the following sections:

- Body postures  
- Actual work space  
- Visual conditions  
- Work surfaces  
- Physical supports  
- Tools and controls  
- Motion sequences  
- Environmental influences

and includes a total of 138 items per workplace for rating on a scale of 0 - 5 by an analyst trained in ergonomic workplace design. The ratings are defined as follows:

[0] not applicable, cannot be fulfilled, need not be fulfilled  
[1] although attainment of goal possible, no evidence of even the most rudimentary attainment discernible  
[2] rudimentary attainment of goal, but only as a trend «in the right direction»  
[3] goal attained to a certain extent, but result not particularly impressive  
[4] goal more or less attained, but improvements still appear possible  
[5] goal attained and even surpassed (only in a few items)
The following procedure was used to collect the data in the production plants: After selection of the reference workplaces at each plant and analysis of production flow and logistics at the workplace and in the production building, each individual workplace was rated with the checklist. We also prepared descriptions of the work sequences and documented them photographically.

Tables showing degrees of goal attainment for each workplace were then prepared. The degree of goal attainment is calculated by taking the ratings of all relevant checklist items for each workplace to obtain an overall percentage figure indicating how far the design status of the workplace is removed from the optimum (100 % = best practice).

A deficiency profile was then plotted for each workplace, for groups of workplaces and for each plant from the ratings of Stage [3] or worse. Fig. 2 shows an example of how the profile is interpreted: Each bar of the profile represents the rating as defined above. The shorter the bar, the greater is the extent of the deficiencies revealed and the more urgent is the need for the relevant redesign features.

The SPSS statistics package was used to perform a cluster analysis of the checklist ratings, which would reveal design deficiencies pervading all departments or all of the plants. The analysis of design deficiencies was followed by the design of an optimized standard assembly and inspection workplace for introduction at all plants. A training program and qualification was also designed and introduced for workers performing inspection activities.

3. RESULTS

3.1 Initial status

All work activities at each production plant are defined in instructions displayed at the workplace. Workers are instructed to perform visual controls of the parts on arrival at their workplace before processing and before leaving their workplace after processing. Defects thus discovered must be either shown to the foreman or recorded in a report.

However, the high proportion of temporary staff working at the plants makes it difficult to ascertain the extent to which prior training received by them is sufficient to ensure accurate assessment of quality.

Integrity of form is normally verified when the fender emerges from the injection molds. This is done visually or by tactile tests of the surfaces. All parts are inspected under reflected light after painting. Parts exhibiting defects are marked and returned immediately for reworking.

The fender is inspected for quality and damage before being released for assembly. Minor defects are repaired by the quality controller at a workbench. The front fenders emerging from assembly are checked for compliance with order, integrity and damage, and are then fitted with extra components for special models. The testing procedure lasts around 0.95 min, plus 0.15 for transportation time. Fig. 1 below shows an anthropometrically unsatisfactory inspection workplace requiring the worker to adopt highly unfavorable body postures.

The following serious design deficits were discovered at nearly all of the assembly and quality-inspection workplaces:

- body position and posture
- actual work space
- visual conditions
- work surfaces
- motion sequences and
- environmental influences.

Wrong selection and poor training of workers, design of work sequences, lack of order and poor state of tools and equipment were frequent sources of inspection errors and included the following specific items:

1. Complicated handling arrangements and collision risks on the conveyors increased fender transit time and damage risk.

2. Inclusion of a final quality inspection relieves the individual workers farther back on the line of part of their responsibilities. This means that parts already defective on arrival from the warehouse or damaged during assembly may be ejected from the process too late.

3. Splitting of the assembly operation into several steps reduces the job content of each worker. The act of hammering the facings into the fenders places high stress on the hand-arm system and involves high frequencies, high exertion, vibrations, unfavorable body posture and little opportunity for changes in work activity. The risk of disease, especially repetitive strain injuries (RSI), is extremely high at these workplaces. Another stress on the
workers is the need to carry the fenders in an unfavorable posture (arms above the head) from the workplace to the conveyor.

4. The transport frame provided by the employer causes logistic problems due to the fact that the back fenders cannot be loaded by one man alone. The instructions for arrangement of the front and back fenders onto the frame make it necessary to find temporary storage for these parts.

![Figure 1: Body posture during preparation of fender for quality inspection](image)

Fig. 2 shows an example of a job design profile exhibiting the deficits revealed by the analysis.

The collected data can be used to summarize the workplace design deficiencies at all of the five plants in a hit list. It stands to reason that the most logical procedure will then be to start by addressing those deficiencies applying to a large number or even all of the workplaces (Tab. 1).

Typical of all of the production plants visited by us are the logistic deficiencies in the production areas and at the workplaces. Materials and product flows seldom correspond to the logical manufacturing process sequence. The result is superfluous multiple transport operations, overlong transport distances, need to provide interim storage and a high level of work operations, all of which are detrimental to productivity.

One reason for these logistic problems is antiquated plant layout or use of buildings not originally designed for manufacturing operations. The remaining logistic problems are homemade and several of them could be eliminated by minor capital expenditure.
### 3.2 Improved conditions

Three main problems need to be addressed in order to improve working postures:

1. Reach areas
2. Field of vision
3. Room for foot movement

Allowance was made for the following aspects when designing the proposed standard workplace. The ideal solution is to have all of the work objects within easy reach of the worker, so that no forward inclination of the body is necessary. The reach area should be subdivided into “large” and “small”, the large reach area being the area reachable by movements of the upper and lower arms. This must be calculated for extremes ranging from the largest men to the smallest women and it is also necessary to make due allowance for the tolerability of frequently occurring reaching movements. This tolerability depends mainly on the level at which the frequently occurring movements have to be performed, for which lifting to shoulder level should be regarded as a maximum. All frequent work operations at above shoulder height must be eliminated as potentially injurious to health. A simple, height-adjustable, revolving structure enabling optimal performance of assembly and inspection work from the 5% woman to the 95% man was proposed (Fig. 3).

Another feature is the kinematical link on the receptacles for small parts, which always remain at the same distance from the fender. Because they are not needed for every operation, they are located in the large reach area. When the fender is correctly positioned at elbow height, these receptacles can be reached by the 5 to 95 percentiles at a level well below shoulder height. At some of the workplaces where parts are automatically delivered, there is a balancer within the reach area, onto which the worker can place tools at below shoulder height. In cases where parts have to be delivered to a workplace, it is also necessary to provide a conveyor system delivering them to within easy reach of the worker.
Table 1: Profile of n=59 assembly and inspection workplaces at five production plants, frequency of defects (=Ratings 1–3 on rating scale) for 60 of the items evaluated.

<table>
<thead>
<tr>
<th>Item</th>
<th>Workplace design defect</th>
<th>Frequency (%)</th>
<th>Item</th>
<th>Workplace design defect</th>
<th>Frequency (%)</th>
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<tr>
<td>13</td>
<td>Load handling</td>
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<td>125</td>
<td>Avoidance of stumbling blocks</td>
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<td>135</td>
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<td>Arm-, abduction angles</td>
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<td>44</td>
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<tr>
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</table>

Adjustments to different working heights should, for time-saving reasons, be made automatically during conveyance of the work objects, and each worker should be able to select the most comfortable working position for him- or herself (depending on the work being performed) once during the shift.

The structure must be rigid at top and bottom to enable it to absorb forces acting vertically to the frame. Without this, it is impossible to construct a structure that is sufficiently stable for assembly operations and, at the same time, enables individual adjustment of the fender inclination.

The small reach area must be “visually accessible” and the line of sight should in most cases run at a slightly downward angle in order to enable the worker to keep neck and shoulders muscles relaxed. In activities requiring a high degree of visual input, it should be assumed that the worker will adjust his or her posture to a visual distance of around 40 cm.

The fender and the receptacle for small parts are readily visible at all times in the standard workplace solution, and the facilities for height and swivel adjustment enable the worker to find the optimal position for all key visual tasks. It also gives the worker adequate room for foot movement, which in turn enables him or her to maintain an upright posture.
4. DISCUSSION

The following suggestions for improvements have now been put into effect:

1. Standardization of workplace fittings (in particular facilities for holding tools) and of working heights at all production plants have yielded improved ergonomics and will reduce levels of worker fatigue.
2. The subject of body postures receives high priority in the productivity improvement groups. Training in good ergonomic behavior (e.g. back and lifting courses) is available. The productivity improvement groups themselves have made suggestions (involving no additional capital expenditure) for workplace redesign. This can also be expected to yield positive effects in due course.
3. The question of production area and workplace logistics was addressed by a productivity improvement group from all five plants with the aim of eliminating unproductive movements of materials. This group

   • made a critical review of all materials movements;
   • eliminated as far as possible all non-productive movements of materials;
   • arranged for work materials and tools to be located optimally for performance of the work process.

5. REFERENCES
