Proceedings of the

FIFTEENTH CONFERENCE

of the

INTERNATIONAL FOUNDATION FOR PRODUCTION RESEARCH

ICPR–15 Manufacturing for a Global Market

9th - 12th AUGUST 1999

Volume II

Department of Manufacturing and Operations Engineering
University of Limerick
Limerick
Ireland

TECHNICAL AND HUMAN ASPECTS OF WELDING WORK – ANALYSIS OF EFFICIENCY AND ERGONOMICS OF TWO WORKSTATIONS

T. Engström[1], G.-Å. Hansson [2], T. Möller[3], K. Ohlsson[2], J. Unge Byström [2]

1 – Department of Transportation and Logistics, Chalmers University of Technology, Gothenburg, Sweden.
2 – Department of Occupational and Environmental Medicine, University Hospital, Lund, Sweden.
3 – National Institute for Working Life, Solna, Sweden.

Tomas Engström, Department of Transportation and Logistics, Chalmers University of Technology, SE-412 96 Gothenburg, Sweden, Phone +46 31 772 1348, toen@mot.chalmers.se

Key words: electromyography, efficiency analysis, muscular rest, production system design.

ABSTRACT:

This paper reports a case study focused on evaluation of manual welding work. The evaluation was performed in terms of measurements of work efficiency by means of video recordings and simultaneously the physical work load by assessing muscle activity and work postures and movements. One result was that the work efficiency in the form of actual welding, compared to non-value adding work activities (such as positioning and handling of the welding pliers), represented 14 – 15% of the total work performed on the workstations. As to the muscular activity, the value adding work at the most physically demanding workstation meant a much higher load and less rest for the extensor muscles. Such an increase was not evident for the trapezius muscles.

1 INTRODUCTION

Evaluating modern production systems which consist of a complex mix of man and machines calls for a rational analytical evaluation procedure. This is critical, as human aspects must be considered. When there is an ambition to integrate ergonomic issues in the design procedure of e.g. a new plant, usually the technical issues are given priority, since these issues call for immediate action. Thus, optimisation of production systems is in practice often focused on output aspects, thus excluding the dimension of physical workload. The aim of this study was to evaluate the performance in terms of measures of work efficiency and simultaneously the physical workload, when welding. Another aim was to decide whether or not the two workstations, chosen as extremes by the practitioners, were correspondingly extreme as to the quantitatively assessed physical workload.

2 THE CASE STUDY

This case study focused on welding in an automotive plant. This specific plant comprises a mechanised production system for the manufacturing of automotive components with a mix of automatic and manual workstations, see [1] for a more detailed description. The production system studied consists of robots, turn tables, lines, miscellaneous transport and transfer equipment for products and fixtures, etc. The manual work was extensive and the number of robots limited. Most of the manual work was characterised by swinging heavy welding guns. The production system was still under running in. There were in fact numerous technical, as well as organisational details, still to be sorted out. Two representative, but extreme, manual workstations were studied. The workstations were denoted #1 and #2 with #2 considered having the most extreme physical workload by practitioners in co-operation with operators and engineers. Thereby assuming that the exposure of similar magnitude on the other workstations represented a physical work load somewhere in between these workstations. One female and one male operator were chosen for the case study. They were chosen for being representative for the work force as a whole.

3 METHODS AND MATERIALS

The case study comprises two main aspects, one technical and one human. Aspects which have been operationalized in the form of work efficiency and physical work load.

3.1 Work efficiency by means of production losses

The work efficiency was detected by means of so-called production losses based on video recordings using a special video recorder synchronised with a personal computer [2]. This method for assessing detailed analysis of various work activities may be defined according to the purpose of the analysis. This specific equipment has proved to be valuable in grasping detailed shop floor data, especially so, as some of the production losses are generated by inter-operator and intra-operator variation. Variations which, depending on the production system design might generate idle operator time and/or need for re-work, i.e. production losses calling for extra man-power [3]. In the case study we have distinguished between value and non-value adding work activities. Note that this analysis is not strictly in accordance with [3] since the original findings are primarily based on computer simulations taking account of the dynamic factors. The results presented here, however, are focused on the workstation levels regardless of whether or not e.g. the observed waiting times were in fact generated by intra-operator variation.

3.2 Physical work load by means of muscular load of the m. trapezius and the forearm extensor muscles.

Bipolar electromyographic (EMG) registrations were made by surface electrodes [4]. For the trapezius (neck/shoulder) muscle, the electrodes were placed on the descending part. For the forearms, the placement was over the extensor muscle bellies, one third the forearm length from the elbow. The muscular activity was characterised by the root mean square value of the of the EMG signal and normalised to the maximal electrical activity (MVE) provoked by maximal voluntary contractions (MVC) [5]. The 10th, 50th and 90th percentiles of the amplitude distribution function (APDF) were used for description of the muscular activity, as well as the proportion of muscular rest, defined as the proportion of time spent with a muscular activity below a threshold level [6].

3.3 Physical work load by means of postures and movements of the head and upper arms.

Inclinometers were used to measure the angle relative to the line of gravity. One was placed on the forehead and two on the upper arms. The angles and their time derivates of the different projections, were used to describe the postures and movements [4]. All measurements concerning the physical workload were made simultaneously and bilaterally. Data loggers were used for all data acquisition.

4 RESULTS

4.1 Work efficiency

The observed work efficiency according to the method described briefly above on the workstations #2 is presented in Table 1. However, both workstations could be evaluated by this method, as our data provides this opportunity. In fact this analysis procedure was later, after this specific case study, developed further since one critical aspect is how to synchronise the technical recordings of e.g. EMG with the video recordings [7].

	Manoeuvring and welding:	Materials handling:	Cementing:	Handling of welding fixture:	Grinding:	Miscellaneous:
Work-station #1						
Female:	34.3	0.0	10.5	14.9	0.2	40.1
Male:	35.5	0.0	21.5	17.6	0.1	25.3
Work-station #2						
Female:	57.4	16.4	5.0	4.1	0.2	17.0
Male:	60.0	14.4	3.0	8.9	0.0	13.7

Table 1. Work efficiency for the manual workstations #1 and #2 for the male and female operators expressed as a percentage of the observed work [1].

The video-based analysis was performed in two phases. First by dividing the work into detailed sub-activities chosen in order to understand and describe the observed work. Secondly, these sub activities were grouped into clusters of work activities. However, these details are omitted in this paper. The various work activities chosen were; (1) manoeuvring and welding, i.e. welding, positioning of the welding gun, move welding gun, and fetching and leaving the welding gun, (2) materials handling, i.e. fetching and positioning of components to be welded, (3) cementing, i.e. adding putty and moving cementing equipment, (4) handling of welding fixture, i.e. moving, rising or lowering, connecting air hoses to the welding fixture, (5) grinding, i.e. grinding, moving grinding equipment, fetching and leaving grinding equipment, i.e. some grinding was necessary and some grinding will later be omitted during the ongoing running in process and (6) Miscellaneous activities, i.e. documentation of quality, cleaning, etc. These work activities are ranked in accordance with the value adding perspective, where welding is viewed as the "most valuable", representing the activities manoeuvring and welding which might be assumed to be "most valuable" since it represent manual work which adds something to the product which in fact can not be avoided. The results are shown in Table 1. These results are based on video recordings. The activities are defined according to an analysis procedure earlier utilised for evaluating manual assembly work [8].

4.2 <u>The physical work load</u>

Considering both workstations and both operators, the muscle activity in the right trapezius muscle for the 10th percentile ranged from 0.8 to 2.3 %MVE for the right side and 1.1 – 2.5 for the left side. For the female operator all percentiles were somewhat lower for the workstation #1 than for #2 for both sides. Opposite values were found for the male operator. Muscular rest, i.e. the proportion of time spent below the threshold limit, was low for both operators, both workstations ranging 1 – 10%. As to the activity in the extensor muscles, the values ranged from 0.6 to 4.8 %MVE for the 10th percentile for the right side and from 0.2 – 1.1 for the left side regarding both workstations and both operators. However, work at the workstation #1 resulted in lower activity for all percentiles. This was the case for both sides. Moreover, the proportion of rest was smaller for the right arm compared to the left, for both operators. Work at the workstation #1 also implied more rest for both operators. Comparisons of normalised muscle activities were assessed through combined analyses of the relation between value adding and non-value adding work tasks, regarding various aspects of muscle activity, and could be presented in a comprehensive graph (Figure 1). The 10th, 50th, 90th and 99th percentiles are shown, as well as the muscular rest. The trapezius muscles as well as the extensor muscles for both operators are shown. We found that almost all percentiles were lower for the value adding work for the trapezius muscles for both operators, most evident for the left side. The proportion of rest was higher for both operators.. This was also the case for the 10th percentiles for both operators. However, for one operator, the value adding work resulted in higher values for the 50th and 90th percentiles. The proportion of rest was higher for both operators. When regarding the extensor muscles, the overall impression is that the value adding work implied higher activities, especially so for the lower percentiles and the rest periods were lower. As to the postures of the head, work at the workstation #2 meant, for the female operator, a somewhat more forward bent position (values for the male operators are missing due to technical problems). Regarding the position of the arms, the female operator held her arm in a more forward/outward position than the male operator, for half of the registered time (50th percentile) except for the left arm at the workstation #2. The angle was more than 30° most of the time for both arms for the female operator and for the left arm for the male operator. These positions indicate a high load on the structures of the shoulder joints. As to the velocities, the male operator showed higher values for both arms

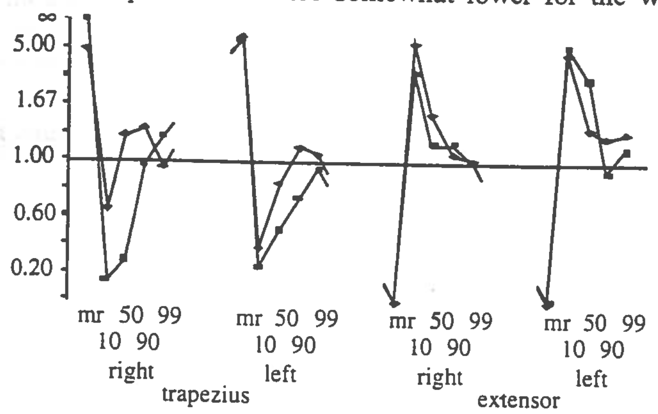

Figure 1. The value-adding activities (welding, moving and adjusting the welding gun) in relation to the non-value adding activities at the workstation #2. The 10th, 50th, 90th and 99 percentiles, as well as muscular rest (mr), are shown for the two operators and the trapezius and the extensor muscles bilaterally. The graphs represent the two operators.

and both workstations than the female operator. Comparing the two workstations, the female operator had a higher velocity at the #2 workstation at the 50th percentile. This was also the case for the head.

5 CONCLUSIONS AND FINAL COMMENTS

The aim of this study was to (1) evaluate the performance and the physical workload in terms of measures of work efficiency and (2) illuminate weather or not the workstations chosen by the practitioner as extreme, also showed a quantitative high work load. On the whole the physical workload, regarding the muscle activity as well as postures and movement, on workstation #2 was higher than on the workstation #1. As to the muscle activity, this was most evident for the extensor muscles. The activity levels for the trapezius muscle at #2 was about the same as for other industrial work e.g. assembly work. The load on the forearm extensors was somewhat higher for both workstations when comparing with other industrial work according to our experiences. One would expect a much higher load in the right than in the left side in this type of work. This was not always the case. However this might bee explained by the fact that the operators relieved the load or the arm on the welding gun while working. Note that since the case study was carried out in 1998 the production system have been extensively rebuilt, e.g. workstation #2 was been robotized partly based on the result reported here. A fact that indicates the value of the type of analyses schetched in this paper. The work efficiency in the form of actual welding, compared to non-value adding work activities (such as positioning and handling of the welding pliers), represented 14 – 15% of the total work performed on the workstations. As to the muscular activity, the value adding work at the workstation #2 meant, for both operators, much higher load and less rest for the extensor muscles. Such an increase was not evident for the trapezius muscles.

ACKNOWLEDGEMENT: The Swedish National Institute for Working Life in form of the research programme; Co-operative for Optimisation of Industrial Production Systems Regarding Productivity and Ergonomics.

REFERENCES

[1] Petersson, P., Utvärdering av arbetsinnehåll och arbetsbelastning vid Autonovas Karossfabrik, Avdelningen för Arbetsmiljöteknik, Lunds Tekniska Högskola, Lund samt Institutionen för Transportteknik, Chalmers Tekniska Högskola, Göteborg, 1998 (M.Sc.-thesis).

[2] Medbo, P., Input Quality in Materials Flow Analysis, Department of Transportation and Logistics, Chalmers University of Technology, Gothenburg, 1998 (licentiate thesis).

[3] Wild, R., On the Selection of Mass Production Systems, International Journal Production Research, Vol. 13, No. 5, 1975, pp 443–461.

[4] Åkesson, I., Hansson, G.-Å., Balogh, I., Moritz, U., Skerfving, S., Quantifying Work Load in Neck, Shoulders and Wrists in Female Dentists, International Archive Environmental Health, No. 69, 1997, pp 461–474.

[5] Hansson, G.-Å., Asterland, P., Skerfving, S., Acquisition and Analysis of Whole-Day Electromyographic Field Recordings European Applications of Surface Electromyography, the Second General SENIAM, Surface EMG for Non Invasive Assessment of Muscles Workshop, Hermens, H. J., Hägg, G., Freriks, B. (eds.) Stockholm, proceedings, 1997, pp 19–27.

[6] Nordander, C., Hanson, G.-Å., Atserland, P., Ballough. I., Byström. B., Ohlsson. K., Skerving, S., Muscular Rest a Measure of Physical Exposure, the International Ergonomcis Association 13th Trennial Congress – IEA 97, Organizational Design and Management", Seppälä, P., Luopajärvi, T., Nygård, C.-H., Mattila, M. (eds.), proceedings, Tampere, Vol. 4, 1997, pp 207–209.

[7] Forsman, M., Engström, T., Hansson, G.-Å., Medbo, L., Asterland, P., Evaluation of Manual Work by Synchronising Video-Recordings and Physiological Measurements, the 15th International Conference on Productions Research, Limerick, 1999 (manuscript).

[8] Engström, T., Medbo, L., Empirical Analysis and Assessment of Automotive Assembly Work: An analyse procedure for work efficiency and ergonomic aspects, the International Ergonomcis Association 13th Trennial Congress – IEA 97, Organizational Design and Management", Seppälä, P., Luopajärvi, T., Nygård, C.-H., Mattila, M. (eds.), proceedings, Tampere, 1997 pp 171–173.