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Method for Assessing the Reduction of the Risk of Musculo-skeletal Disorders by Using Ergonomically Designed Vibrating Tools

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Abstract

The CUELA system for registering bodily posture and load handling during work, developed by BIA, has been used for the quantitative evaluation of the reduction in health risks by excessive stressing of the body during grinding work in a shipyard. The conventional angle grinder, used in crouching body position was replaced by a belt sander, operated in standing position. The vibration exposure has been reduced from 10.7 m/s^2 to 0.96 m/s^2 (total vibration value). The ergonomic assessment of the grinding work results in a minimisation of potentially harmful body postures from 90.9 % of working time with the angle grinder to 6.2 % using the belt sander.

Introduction

Bone and joint damage of the upper extremities has been recognized as an occupational disease in Germany since 1929. Initially only applying to mining, it has subsequently been extended to other branches of industry, and especially to the construction industry. More than 500 workers in German industry apply annually to have this type of disease recognized as an occupational disease. The EU Directive 2002/44/EC on the protection of workers from vibration cites the elimination of the causes of muscular and skeletal injury as an important preventive aim.

EU-Directive 2002/44/EC: Taken from legal arguments (3) –

... to introduce measures protecting workers from the risks arising from vibrations owing to their effects on the health and safety of workers, in particular **musculo/bone structure**, neurological and vascular disorders.

In order to enable firms using vibrating tools to select especially low-emission vibrating devices, manufacturers on the European Single Market are obliged to list the devices' vibration emission values in the information for the user. In its essential safety requirements, the EU Machinery Directive 98/37/EC also demands for hand-held and hand-guided machinery that ergonomic design principles receive special attention when such equipment is designed. Manufacturers can document to the user the achieved reduction in vibration by quoting the vibration emission values.

EU-Directive 98/37/EC: Taken from annex 1 (essential safety and health requirements) –

1.1.2.(d) – Under the intended conditions of use, the discomfort, fatigue and psychological stress faced by the operator must be reduced to the minimum possible **taking ergonomic principles** into account.

1.5.9 – Machinery must be so designed and constructed that **risks resulting from vibrations** ... are reduced to the lowest level....

2.2 – Portable hand-held and hand-guided machinery – The instructions must give the following information: **the weighted r.m.s. acceleration value ...** if it exceeds 2,5 m/s^2.

However, any reduction in health risks or in excessive stressing of the body due to the ergonomic improvements mentioned can usually only be qualitatively assessed and not objectively measured. By taking the example of an ergonomically modified grinding workplace in a shipyard, we wish – in addition to the measurement-based demonstration of the achieved reduction in vibration – to present the CUELA method (computer-supported registration and long-term analysis of musculo-skeletal load) for the measurement-based characterization of changes in ergonomic loading [3].

Grinding Workplace in a Shipyard

Figure 1:
Preparation of the weld seam with an angle grinder

Figure 2:
Preparation of the weld seam with a turbo belt sander

Traditionally, the manual grinding of horizontally laid iron plates to prepare the weld seam is an important work process in shipbuilding. The advance preservation of iron plates has considerably increased the extent of manual grinding, as the paint film has to be removed prior to welding. Conventionally, the worker guides the electric angle grinder in a crouching position. To relieve the spine, he kneels on the cold iron plate. The grinder is situated at arm's length below the face, and the operator is exposed not only to vibration and noise, but also to inhaled dusts and vapors. The goal in improving this working method, which is health-hazardous on several counts, was to enable grinding to be carried out with an upright body posture. To this end, the shipyard converted a conventional electric angle grinder into its own turbo belt sander. The grinder can then be operated in much the same way as a lawnmower, with the operator walking upright. The guide bar permits precise adherence to the marked grinding track and the application of the required pressure to the grinding belt. Thanks to the greater distance between the face and the grinding process, the quantity of dusts and vapors inhaled is reduced. The typical out-of-balance vibrations of the rotating grinding disc on the angle grinder do not occur on the belt sander. The achieved ergonomic improvement is obvious. By using the CUELA system, we wish to quantitatively assess this improvement.

Measurement Results

Vibration Load

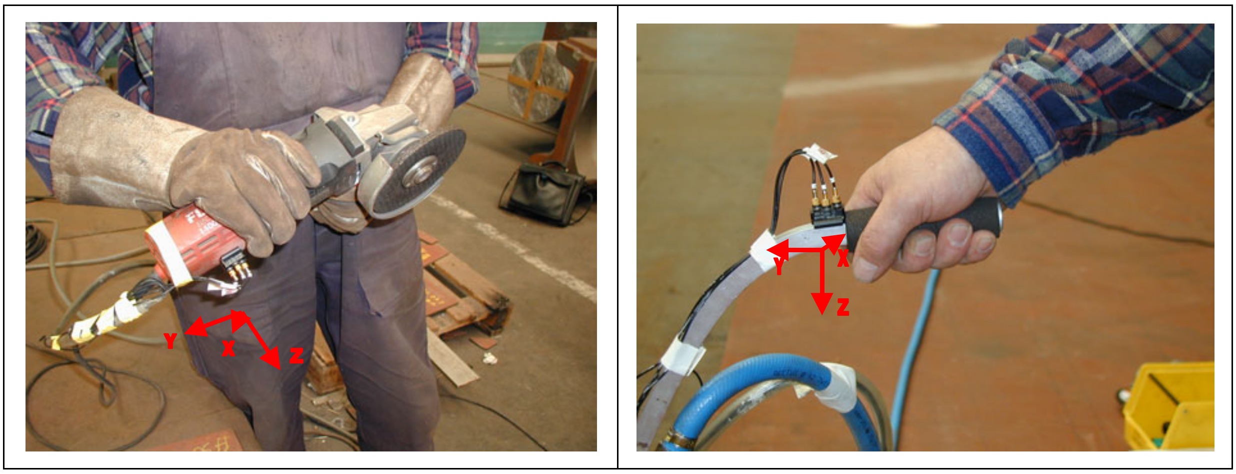


Figure 3: Accelerometer mounting and coordinate system

To determine the vibration exposure, the accelerometers for the x-, y- and z-axes were attached to the tool's handgrips immediately next to the hand in accordance with ISO 5349, Part 2. The frequency-weighted hand-transmitted vibration values $a_{hw(x,y,z)}$ were determined for all three measurement axes. The total vibration value a_{hv} was also calculated.

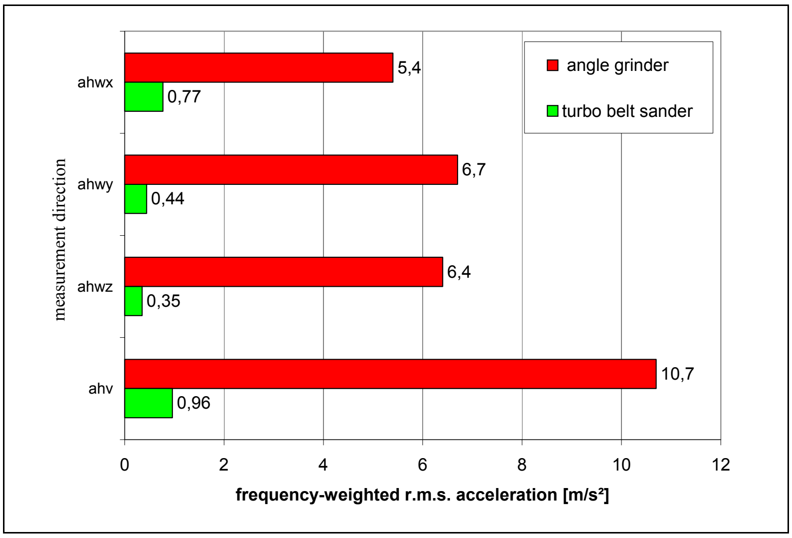


Figure 4:
Vibration exposure
– measurement results

The figure containing the results of vibration measurement for the conventionally used electric angle grinder and the new turbo belt sander show the anticipated, marked drop in the effects of vibration. The frequency-weighted acceleration values from work with the hand-held angle grinder range from 5.4 m/s^2 (x-axis) to 6.7 m/s^2 (y-axis). The total vibration value is 10.7 m/s^2. For the hand-guided turbo belt sander, values between 0.35 m/s^2 (z-axis) and 0.77 m/s^2 (x-axis) were measured. The total vibration value for this has been calculated to be 0.96 m/s^2.

Ergonomic Assessment With the CUELA System

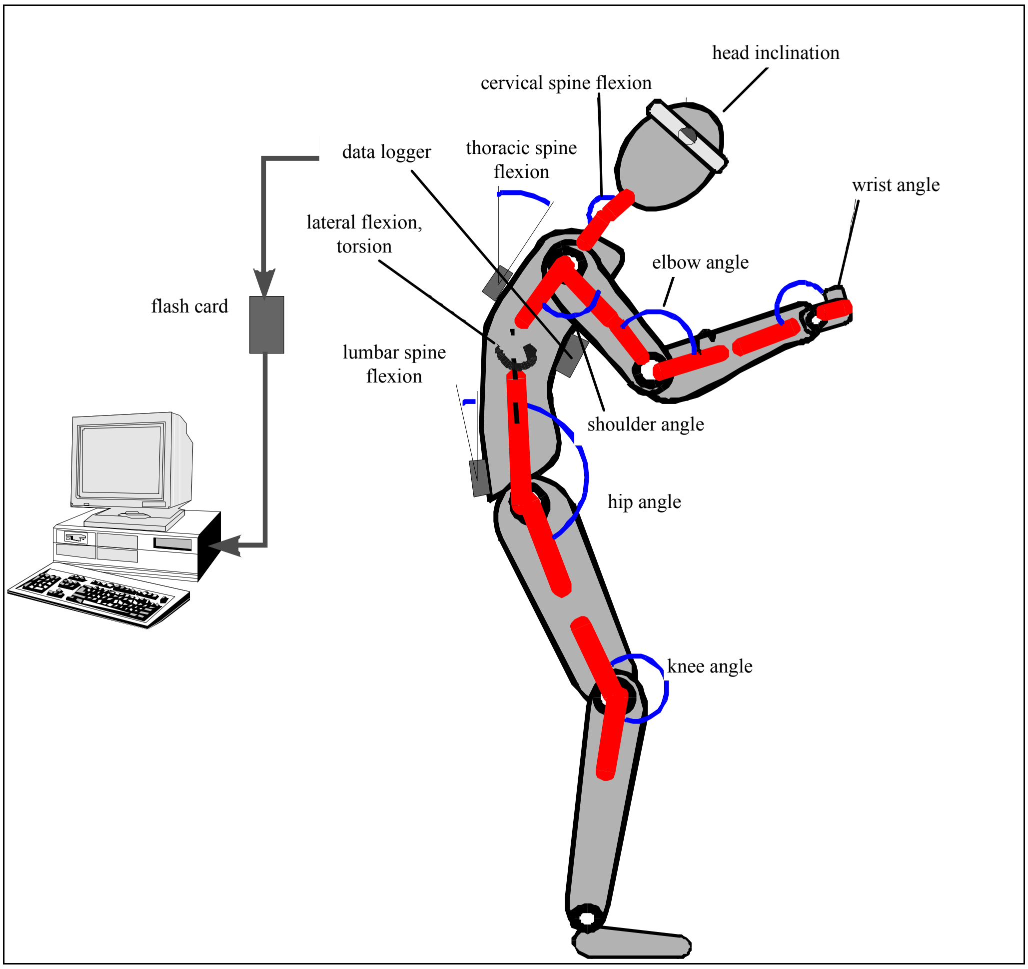


Figure 5: Measurement and storage of body angles during grinding work

Until now, motion studies to determine incorrect musculo-skeletal posture at the workplace have been conventionally carried out with visual methods or by evaluating individual frames of video recordings. This is not only insufficiently accurate, but also time- and labor-intensive. The CUELA system permits high accuracy with a low input of time and labor. It consists of advanced sensors (inclinometers, gyroscopes, potentio-meters) and a portable minicomputer attached to the working person's clothing. This means that the CUELA system is suitable for use not only in the laboratory, but also at any workplace without hampering the person's movements in the performance of his/her work.

Table 1: CUELA system: Measured body angles and types of sensors

Joint/bodily region	Degree of freedom	Measuring sensor
Head	Inclination, flexion/extension	Inclinometer
Cervical vertebrae	Flexion/extension	Calculated
Dorsal vertebrae/Lumbar vertebrae (seperately)	Inclination, flexion/extension, side inclination	Inclinometer, gyroscope
Pelvis	Inclination (sagittal)	Inclinometer, gyroscope
Hip joint	Flexion/extension	Potentiometer
Knee joint	Flexion/extension	Potentiometer
Scapula	Depression/elevation, anterior/posterior	Potentiometer
Shoulder joint	Flexion/extension, ad-/abduction, inner/outer rotation	Potentiometer
Elbow joint	Flexion/extension	Potentiometer
Forearm	Pro-/supination	Potentiometer
Hand joint	Flexion/extension, radial/ulnar duction	Potentiometer

The relevant load data from the sensors for the hand-arm-shoulder system and also for the middle and lower regions of the body are stored with high time resolution (scanning frequency 50/s) on a flash card in the minicomputer fastened to the person. It is possible to store all the sensor data for the period of a complete work shift lasting 8 hours. Immediately after work, the data are transferred to another computer, where they are directly available for evaluation. The CUELA software developed for this application by the BIA permits the visualization of the recorded joint angles and body pitches and rotations at any measured point in time with the aid of a 3-dimensional computer figure. A video image recorded at the same time is automatically displayed.As an example of this, the flexion, adduction and inner rotation of the shoulder joints during grinding work are displayed. Clearly visible is the repetitive motion with the angle grinder (pay attention to the scaling) during work in a crouching or kneeling position. By comparison, the equivalent motions during work in an upright posture with the turbo belt sander are much less pronounced.

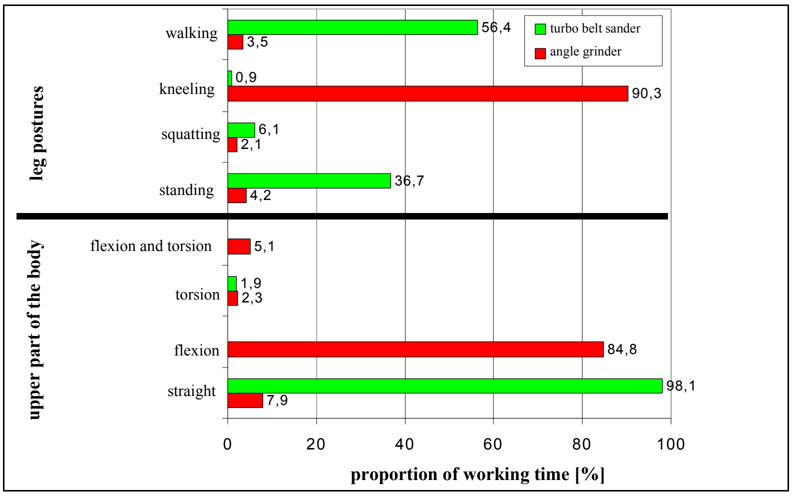


Figure 6:
Analysis of working postures recording

Comparing the two work processes, the figure showing the results of the body posture analysis highlights the elimination of the unfavorable kneeling position and the severe bending of the trunk. During grinding with the turbo belt sander, the upright, unrotated posture of the upper body predominates.

For the assessment of the body posture measurement results, the OWAS method (Ovako Working Posture Analysing System) developed in Finland was employed [5]. To this end, a total of 252 different body postures were classified and assigned statistically to four action categories. The user is thus given a list of priorities for the ergonomic design of the work process. After taking certain measures, the CUELA system makes it possible to monitor performance and optimize the measures if required.

Categorization of totally 252 postures combined with loads handled and classified to 4 risk categories ("action categories"):

Action category 1:	No action necessary
Action category 2:	Action must be considered during the next regular check
Action category 3:	Action necessary in the near future
Action category 4:	Action necessary immediately

Figure 7: Ergonomic assessment (categorization) by OWAS

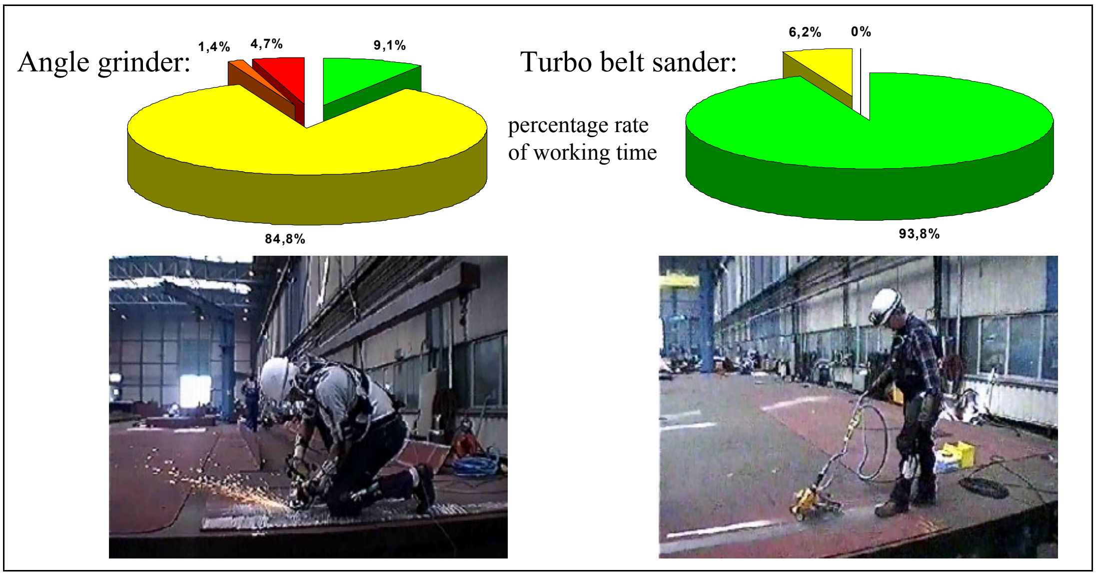
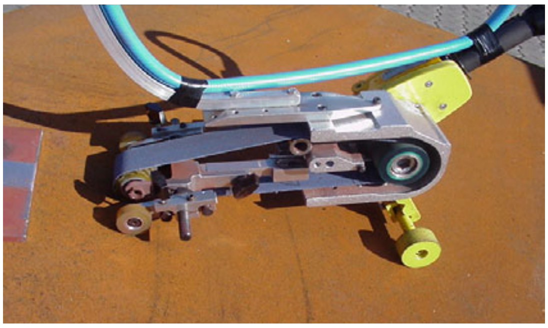


Figure 8: Assessment of musculo-skeletal risks at the grinding process: Action categories for preventive measures

The OWAS analysis showed that, during work with the angle grinder, no need for ergonomic improvement was identified for only 9.1 % of working time. During 90.9 % of working hours, the adopted posture is therefore considered potentially harmful to the musculo-skeletal system. By using the new grinding method with the turbo belt sander, 93.8 % of working time is considered non-injurious to health. Only 6.2 % of working time is assigned here to action category 2.

Conclusions



Self constructed turbo belt sander:
- no musculo-skeletal risks
- low vibration exposure
- high grinding power

240 meter weld seam prepared by grinding with the turbo belt sander within 28 minutes

Figure 9: Successful ergonomic design of grinding work

The successful example of the use of a hand-guided belt sander instead of a hand-held angle grinder shows that the effective reduction in the vibration exposure is also capable of yielding major ergonomic improvements at the same time. As proof of their effectiveness, the combination of both measures to improve occupational health and safety – one of the key demands of the EU Machinery Directive – requires not only the measurement of the key vibration data, but also an objective, checkable assessment of the ergonomically enhanced design. The CUELA system developed by the BIA has proven ideal for this. The ergonomic design of vibrating hand-held and hand-guided tools must also take account of the physical effort of operating staff in the envisaged applications at the workplace and if necessary provide suitable guidance for handling.

The employer is in a position to make a considerable improvement to health-hazardous working conditions by selecting suitable equipment and working methods. The declaration of the vibration emission values demanded by the EU Machinery Directive for all hand-held and hand-guided tools represents an important step in this direction.

Ergonomic improvements result not only in a reduction in musculo-skeletal loads and thus to a reduction in the level of illness-related absence from work, but can also yield direct economic benefits, as can be clearly seen in the presented example of grinding work in shipbuilding. To grind a 2-m long and 50-mm wide track, the electric angle grinder takes 3.5 minutes. With the turbo belt sander, this task can now be accomplished in 14 seconds.

References

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