Ergonomics in the South African mining industry

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Synopsis

Ergonomics is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. Despite the fact that the application of ergonomics principles can make a major contribution to the management of significant occupational safety and health risks, ergonomics is currently applied on a limited scale in the South African mining industry.

The objective of this paper is to provide a perspective of ergonomics, the main aim being to create a point of departure for the development of strategic objectives to enhance existing health and safety initiatives through the application of sound ergonomics principles. Two of the major consequences of poor ergonomics, namely work-related musculoskeletal disorders and worker fatigue, and possible means of introducing ergonomics into the South African mining industry, are discussed.

Introduction

The International Ergonomics Association defines ergonomics as: 'the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance'.

From a practical point of view, ergonomics is the science and practice of designing systems to fit people. Ergonomists contribute to the design and evaluation of equipment, workstations and work environments so that the tasks required of humans are within their limitations, but also so that the best use is made of their capabilities. The application of sound ergonomics principles in the design of the human-machine interface will minimize design-induced human error, and also eliminate significant occupational health and safety risks. In the workplace, the application of ergonomics aims to promote the health, efficiency and well-being of workers.

'Ergonomics' is not a new concept in the South African mining industry. The Mine Health and Safety Act (Act 29 of 1996) makes specific reference to ergonomics. Section 21(1)(c) of the Act states that: any person who designs, manufactures, erects or installs any article for use at a mine must ensure, as far as reasonably practicable, that ergonomic principles are considered and implemented during design, manufacture, erection or installation.

In an industry-wide risk assessment conducted under the auspices of the Safety in Mines Research Advisory Committee (SIMRAC) in 1997, it was pointed out that poor ergonomics design and the lack of a strategy for introducing ergonomics into the South African mining industry were major contributing factors to the development of work-related injury and disease[1]. A lack of ergonomics research in the local mining industry was also identified as a major shortcoming and contributing factor[2]. In the same project, poor ergonomics that contribute to hearing loss, and the health risks involved in bio-mechanical factors, vibration and heat stress, were highlighted[3].

For the major part of the previous century, research in the field of ergonomics primarily focused on the capabilities and limitations of individuals to perform physical work in conditions typical of gold mining, and the design of selection criteria to assess fitness for work based on an individual's physical attributes. In the latter part of the century the emphasis shifted towards research into the ergonomics of trackless vehicles, locomotives, mining machinery, work-related musculoskeletal disorders, operator fatigue,

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and certain macro-ergonomics issues such as the development of a comprehensive ergonomics strategy to facilitate the co-ordinated and integrated implementation of ergonomics in the South African mining industry.

Despite the fact that local as well as international statistics indicate that ergonomic factors underlie many occupational accidents and work-related diseases, it is surprising that ergonomics is not an integral part of management procedures to ensure health, safety and productivity in the South African mining industry. Basic ergonomics is currently applied to a limited extent in the mining industry. Although there is a growing awareness of the need for ergonomics, very little has been done about its application.

The present paper considers two of the major consequences of poor ergonomics, namely work-related musculoskeletal disorders and worker fatigue, and possible means of introducing ergonomics into the South African mining industry.

Work-related musculoskeletal disorders

Musculoskeletal disorders are a group of conditions that involve the nerves, tendons, muscles and supporting structures needed for locomotion. These disorders can result in anything from mild periodic symptoms to severe chronic and debilitating conditions. The specific term 'work-related musculoskeletal disorders' (WMSD) refers to musculoskeletal disorders to which the work environment and the performance of work contribute significantly, or musculoskeletal disorders that are made worse or longer lasting by the work environment.

The results of a recent a retrospective record review[4], aimed at getting a 'snapshot' of the situation regarding WMSD in the South African mining industry, indicted that 16.2% of the 1 235 medical records examined at a gold mine participating in the study concerned WMSD. Of these musculoskeletal disorders, 15% were associated with the upper limbs, 16% with the lower limbs and 69% with the back region. In the case of the platinum mine used in the study, 41.3% of the 75 medical records dealt with WMSD, and 62% of these WMSD records were associated with the upper limbs, 8% with the lower limbs and 30% with the back region. At a colliery participating in the study, a total of 226 medical records dealing specifically with WMSD were examined. Analysis revealed that 37% of the musculoskeletal disorders were associated with the upper limbs, 13% with the lower limbs and 50% with the back region.

As far as work categories and the development of WMSD on the gold mine are concerned, 43% of the WMSD cases recorded were rock drill operators, 14% general stope team workers, and 12% mechanical loader operators. Occupations at the platinum mine were rock drill operators (18% of the total WMSD recorded), scraper winch drivers, mechanical loader drivers and general stope team workers (5% of the total WMSD recorded was associated with each of these work categories). At the colliery the occupations were continuous miner operators (12% of the total WMSD recorded), shuttle car drivers (8% of the total WMSD recorded) and fitters (7% of the total WMSD recorded).

The above statistics confirm that WMSD are present in the South African industry. The results of ergonomics assessments, conducted as part of the above study, confirmed that many of the known risk factors for musculoskeletal disorders[5], usually in combination, are associated with typical mining tasks. The design and operation of current mining equipment and transport also present ergonomics-related hazards that could impact on the operators' health as well as the ability to work safely and efficiently[6,7].

The implementation of ergonomically sound interventions in the workplace has the potential to reduce the risk of WMSD. Due to the uniqueness of the workplace at mines, generic solutions will not necessarily fully address ergonomics-related risks at all mines. It is therefore recommended that mine-specific ergonomics programmes be considered as a method for the introduction and implementation of ergonomics programmes in the workplace at mines. These programmes should be based on participatory principles to ensure successful implementation by and participation of workers at all levels at the mine. Existing health and safety structures, resources and procedures should be considered for this purpose.

Operator fatigue

Over the past few years there has been renewed interest in the impact of fatigue on occupational safety and health, mainly due to the recognition that sleepiness and fatigue are becoming endemic in the populations of industrialized societies. These factors contribute to human error and, consequently, many (sometimes catastrophic) accidents. Recent estimates of the percentage of injuries and fatalities caused primarily by sleepiness or fatigue diverge considerably, varying from 2% to 41%[8].

A great proportion of human error today is fatigue-related and this state of impairment is a natural consequence of human biology. Any industry that involves 24-hour operations will require part of its workforce to try to override the basic diurnal orientation dictated by their circadian clocks. (The circadian clock effectively programmes people to sleep at night and to be awake during the day and also co-ordinates the daily rhythms that exist in the diversity of physiological and behavioural functions of the human body.)

To maintain alertness and performance, each individual requires a certain amount of sleep. Reducing sleep by one hour per night is sufficient to cause sleepiness, which becomes progressively more severe with each night of restricted sleep[9]. The quality of sleep, particularly its continuity, is also an important factor in subsequent alertness and performance. Reduced sleep is common during shift work, particularly during work at night. It is estimated that 75% of night workers experience sleepiness on every

shift and, for an estimated 20%, it is severe enough to cause them to fall asleep[10].

The disruption of the normal circadian rhythm and its associated effects also apply to haul truck operators in the South African mining industry, as driver sleepiness is a reality and a safety risk. Poor quality and quantity of sleep have been identified as major risk factors in the reduced alertness of haul truck drivers during mining operations[11].

The physiological state of human alertness is the key to human performance, and safe and efficient operations in industrial settings rely on people being at their best, regardless of the time of day or night. In order to achieve and maintain an optimum level of human alertness, Sirois[12] has introduced the concept of 'physiology-based safety'.

Sirois defines physiology-based safety as: 'an objective, systematic, and co-operative process between management and employees to reduce worker fatigue. Physiology-based safety is based on the premise that employers have a basic responsibility, and a business incentive, to establish working conditions that support human performance rather than distract from it. Similarly, employees have a responsibility, and a personal health and safety incentive, to report for work alert and fit'. This co-operative process has the potential to convert the costs associated with fatigue-related incidents and accidents into operating profit, as well as to achieve a higher level of safety and efficiency. It also has the potential to contribute significantly to occupational health and safety in the workplace[12].

A prerequisite for the success of any fatigue management programme is that sound ergonomics principles be incorporated. The prevention of fatigue begins with careful planning of tasks and their scheduling. Tasks should be designed so that extremes of exertion (mental and physical) are avoided. Properly designed work schedules are of critical importance and require participatory planning and implementation. Designing shift systems is a complex issue, and it is important to note that there are no ideal systems that can be simply computed using given criteria. There are, however, certain key ergonomics-related aspects to be considered when designing shift cycles, including speed and direction of shift rotation, duration of shifts, timing of shifts and intervals between shifts—all factors influencing both physiological adjustments and the social life of shift workers.

Implementation of ergonomics

A comprehensive strategy to facilitate the introduction and implementation of ergonomics in the local mining industry on an integrated basis, thereby contributing to initiatives aimed at the management of health and safety risks in mines, was developed in 1999[1].

The proposed strategy involved four groups of role-players, namely government, employers, employees and manufactures/suppliers of mining equipment, on the basis of participatory ergonomics. The specific involvement proposed for role-players entails reviewing of existing legislation addressing ergonomics and the drafting of an ergonomics implementation plan by government, the establishment of formal ergonomics programmes on mines by employers, the active participation and involvement in the ergonomics programmes by employees, and the use of ergonomics design guidelines and specifications suitable for the local user population and mining conditions ('cultural and environmental calibration') by manufacturers/suppliers of mining equipment.

Most mines have, as a result of the requirements of Section 11 of the Mine Health and Safety Act (Act 29 of 1996), established risk management systems, which include elements such as hazard identification, risk quantification, training, audit, feedback and a management system. A formal ergonomics programme should ideally be attached to and integrated in existing risk management systems.

Currently available information on the physical dimensions of South African mineworkers is dated, and very little information is available on their mechanical work capacity. In view of the importance of this information in the design of mining equipment, workstations and mining tasks, a SIMRAC project is currently in progress to determine the functional anthropometry (i.e. those body dimensions that are essential for the design of workstations) and the functional biomechanical strength capabilities of South African mineworkers (both female and male).

In order to assist mines, work in the SIMRAC project will also focus on the development of an ergonomics programme specifically for implementation in the local mining industry, and on piloting the programme at a number of project mines. The piloting of previous research outcomes and the components of the proposed ergonomics programme at a number of project mines will facilitate the differentiation of generic and mine-specific components of the envisaged ergonomics programme. Finally, a handbook dealing with the basic ergonomics applicable to the mining industry will be compiled, and will be complemented by a training CD.

Conclusions

The application of sound ergonomic principles in the South African mining industry has the potential to enhance the effectiveness and efficiency with which human tasks are carried out, and also to eliminate significant occupational health and safety risks.

Although understanding of the contribution of ergonomics to mining in the South African mining industry still appears to be poor, ergonomics as a practice is evolving and will in future become more integrated into overall work management systems.

The costs of implementing the ergonomics strategy should be regarded as an investment with long-term benefits. There will also be benefits that cannot be expressed in monetary terms such as improved human health, safety, comfort and well-being, which are actually the main aims of implementing ergonomics in the local mining industry.

References

1. De Koker, T.H. and Schutte, P.C. A comprehensive ergonomics strategy for the South African mining industry. *SIMRAC Final Project Report: GEN 603*. Pretoria: Department of Minerals and Energy. 1999.
2. Harper, G.S. Current and future risks and causal issues relating to engineering-related issues in South African mines. *SIMRAC Final Project Report: SIMRISK 401*. Pretoria: Department of Minerals and Energy. 1997.
3. Kielblock, A.J. Current and future health risks derived from a health risk assessment of the South African mining industry. *SIMRAC Final Project Report: SIMRISK 401*. Pretoria: Department of Minerals and Energy. 1997.
4. Schutte, P.C., Dias, B., Smith, A.J.B., and Shaba, M.N. A prospective study to assess the prevalence and work-related risk factors in the development of musculoskeletal disorders in the South African mining industry. *SIMRAC Final Project Report: Health 702*. Pretoria: Department of Minerals and Energy. 2003.
5. NIOSH. Musculoskeletal disorders and workplace factors: A critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back. Publication No. 97-141, Cincinnati: DHHS NIOSH. 1997.
6. Mason, S. and Heap, T. The influence of ergonomic design of trackless mining machines on the Health and Safety of operators, drivers and workers. *SIMRAC Final Project Report: Col 416*. Pretoria: Department of Minerals and Energy. 1997.
7. Schutte, P.C. and Shaba, M.N. Ergonomics of mining machinery and transport in the South African mining industry. *SIMRAC Final Project Report: SIM 02 05 04*. Pretoria: Department of Minerals and Energy. 2003.
8. Ferrara, M. and De Gennaro, L. How much sleep do we need? *Sleep Medicine Reviews,* vol. 5, no. 2, 2001. pp. 155–179.
9. Caskardon, M.A. and Roth, T. Cumulative effects of sleep restriction on day time performance. *Psychophysiology,* vol. 18, 1991. pp. 107–113.
10. Åkerstedt, T. Sleepiness at work: effects of irregular working hours. T. H. Monk (ed.), *Sleep, sleepiness and performance*. John Wiley and Sons Ltd, West Sussex, 1991. pp. 129–152.
11. Schutte, P.C. and Maldonado, C.C. Factors affecting driver alertness during the operation of haul trucks in the South African mining industry. SIMRAC Final Project Report: SIM 02 05 02. Pretoria: Department of Minerals and Energy. 2003.
12. Sirois, W. Asleep at the wheel. *World Mining Equipment*. March, 2003. pp. 26–31. ◆