Ergonomic Operational Working Aspects of Forest Machines

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ABSTRACT

Ergonomic forestry issues are very complex. Ergonomics must be applied in the development, design, and construction of forest machines. It is necessary to devote thorough attention to this issue and to carry out detailed analyses of all the factors in order to determine the criteria and parameters for the optimal solutions for working conditions. This will help create the relevant standards and regulations.

Working with a chain saw is risky and has a negative impact on workers' health. Regulation of this activity influences technical, technological, and organisational interventions, which should be supported by preventive measures. This is the reason why famous manufacturers of chain saws have taken different technical measures, which decrease vibrations and noise. It is necessary to also take measures with regard to maintenance in order to support technical measures in practice. To get a more precise knowledge about the values of negative vibrations that negatively affect worker's hands, it is necessary to complete longer and more precise research into the issues presented by different types of chain saws and it is important to consider different types of constructional solutions.

The growth of work productivity in forestry is influenced by implementing modern, more efficient machinery, applied technology, and by improving work-related organization. The use of work time particularly creates the basis for organising work processes, which can be regarded as influencing the level productivity.

This book opens up the possibility for further research in many different fields, such as measurements, evaluations, and conclusions with regard to the vibrations and noise created by chain saws.

Keywords: Forestry, forest, wood, ergonomic aspects of work, harvester, chain saw, vibration, noise.

PREFACE

The growth of work productivity in forestry is influenced a great deal by implementing modern and more efficient machinery, as well as applied technology and improving organization in work processes. The use of work time particularly creates the basis for organising work processes, which can be regarded as an element that influences the level of work productivity. Strategies should be used to focus the growth and control of work productivity in order to provide profitability. Nevertheless, individual parts of the operation process cannot be neglected. This is because unsuitable technology, labour safety, ergonomics, hygiene, and so on will also prevent good results.

Wood is mostly is processed by a chain saw. The engine part of the chain saw is often used as a unit of drive for other machines. A chain saw is often used in forestry for tree cutting and processing. The volume of used chain saws decreases in this industry and they are substituted by harvester technologies. Chain saws are used in silvicultural activities, carpenter workshops, and town parks; firefighters and sculptors also use them. A chain saw is widely used but a very dangerous tool, which can cause serious damage to human health resulting from non-professional usage or inattention.

Work productivity is the source of economic value and makes up economical income. Work productivity is generally expressed by a share of a product or the production quantity related to the amount of work involved. The quantity of the work involved can be measured by various means depending on the level where the indicator is observed. The most frequently observed indicator is production per unit of time unit when using certain machines or tools.

This book is focused chain saws and harvester technologies, as well as the suitable choice of work conditions. It also deals with the ergonomic aspects of the whole cutting process and provides technical descriptions of the machines and an analysis of the production process techniques. It also outlines possibilities for the field deployment of the machinery and analyses the workload of harvester and forwarder operators.

Authors

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INTRODUCTION

Tree processing, from cutting a tree in the stand to the final product (e.g. assortment), is dependent on the energy consumption and speed of individual operations, such as cutting, delimbing, making assortments, manipulation, and its placement in the area of work (in the different stages of the production process there is a tree, a trunk, or an assortment). To ensure the correct function of the whole working chain, it is necessary to optimize every individual working operation. The development of increasingly difficult machines and devices, the use of new progressive technologies, the tendency to decrease energy consumption, the material difficulty of products, requirements to ensure the high reliability of machines, and automation in operation press us to search for the theoretical basics of wood production processes in order to facilitate new forest and wood processing techniques.

Every producer must make an attempt to allow for flexibility in order to satisfy the customer´s needs as best as possible. An important tool that makes production more effective and improves economic indicators is defining the type series with a limited number of machinery categories, which can meet the customer´s demands effectively. At present, harvesters are considered the most modern harvest-transport systems used in forest management. The harvester is a multi-operational harvest machine, which disbranches, cuts, and stores wood in more or less formed piles. All operations are performed within one cycle with some operations occurring simultaneously.

Work with a chain saw is very complicated. A chain saw is defined as a machine in laymen's terms. This definition is incorrect because there is a human involved as an active element.

> The correct definition of a chain saw is a moto-manual working tool (Lukáč, 2003).

The Slovak chain saw market has developed dynamically over the last 10–15 years. In addition to professional chain saws, there are different kinds and models of chain saws that are suitable for ordinary people. The tools used for professional work are characterised by their compactness, preciseness, and construction; they are of a high standard, have along life and are resistant to the negative impacts of loading. Professional chain saws have their strength and force components produced from lighter and special metals. Hobby chain saws are only used for occasional short-term work without extreme loading. They are produced from less resistant materials, which cannot survive situations such as very high bumping. Their components are produced from lower quality materials.

All kinds and models of chain saws (i.e., professional and non-professional ones) have one common technical principle in that their cutting effect is created by rotating a special saw chain, which runs at speeds over 20 $m.s^{-1}$; it is very sharp and it is not covered in the working process. Working with a chain saw is very specific. It requires the operator to be in a very good physical condition, have good coordination of movements, and the active cooperation of other sense organs, such as sight and hearing. Working with a chain saw is risky not only from the point of view of injuries but also from its resulting effects, such as hearing loss and sickness from the vibrations. It is essential to have physical power and skills, which come from knowledge and experience. In every moment of the activity there should be controlled use of the chain saw and harvester. This way, the potential dangerous elements of construction (e.g., an uncovered saw chain) can be eliminated and a suitable rhythm and productivity can be obtained instead.

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ERGONOMIC OPERATIONAL ASPECTS OF WORK OF FOREST MACHINES

Ergonomy in the operator's working environment

Ergonomy consists of two Greek words: *ergo* means *work* and *nomos* means *laws*. It is a scientific specialization, which systematically solves the working system (*human-technique-environment*) to eliminate both the psychological and physical loading effects. It uses the latest knowledge in the areas of biology, technology, and social science. The main goal of ergonomy is to optimise the working environment to obtain good health and safety, as well as a high performance. In 2010, the International Ergonomic Association defined ergonomy as a scientific discipline that is based on understanding interactions between humans and other parts of the system. Applying different methods, theories, and data leads to improved health, comfort, and performance.

> It helps solve and evaluate work, work tasks, products, environment and systems to cover complex needs, abilities and performance eliminations of people (Žiaran, 2001).

Recently, ergonomic principles have also been used in forest technology. Ergonomy is a part of complex solutions to provide care for people. The operator is the most important element because they start the whole production. Measures should not only consider the quality of utility values and obtained productivity, but also the level of risk. This should be mainly focused on preventing damage to human health, particularly the physical and psychological aspects of human loading. Outer factors can negatively influence the working process; these include inappropriate work intensity, the higher performance of machines, and badly organised workplaces and technological processes.

The social impacts of workloads are also an important factor. Long-term loading can be damaging to human health damage. Sensory, mental, and

motoric features are significant in defining the limits of effective measures in technology and work organisation. Using its focus on limited human abilities, it helps to solve mechanical and automatization questions, as well as technical issues adjusted to human possibilities. Mutual interactions and differences between the limited human possibilities and the wide possibilities and parameters of technical devices, as well as the need to constantly increase production, means that there is a significant problem with the current ergonomic methods. It means that, in order to achieve maximum efficiency in an economic manner, it is necessary to use optimal human loading.

The basic goal of any ergonomic solution within forest technology is to obtain suitable working conditions for machine operators, while considering human possibilities and, afterwards, the optimisation of these interactions alongside requirements centred on the fast development of science and technology. This is the reason why it is necessary to study both the functional and human possibilities in forest production to understand these conditions and methods of work activities. Finally, together they lead to mental and physical development; they also improve comfort levels at work and facilitate a high level of occupational health and safety.

> The system approach for ensuring basic points for optimal position of a human as the weakest element of the whole system human-technique-environment enables optimal solution for human work activities, working tool and environment and especially regarding to negative factors (Žiaran, 2001).

Without the analysis of these basic system elements, it is not possible to define optimal and reliable performance or the final success of the given tasks. If the individual parts of the system are in disorder or risky, then there will be a high risk for humans. This is the reason why working tasks can influence the cooperation of functional parts and define human loading possibilities at work, as well as identify higher risks for failures, accidents, or injuries. The solutions for the human-technique-environment system are focused on new technologies, as well as new working conditions and the ability to adapt within the constraints of the human factor.

In forest technology, there have been practical attempts to use ergonomic knowledge, which are particularly focused on:

- Analysis of working conditions and human interactions
- Solutions for the regulation of workloads, which considers human performance limits, and makes modifications to work processes and regimes
- Solutions for the work place and the construction of machines and devices with regard to creating the optimal control conditions
- Workplace design, particularly with regard to disturbing, difficult, or health aspects

Psychological and social aspects of human activity

There are some important consideration regarding human activity, reliability, and performance, especially in terms of brainpower, morale, character, health, and physical conditions. Then there is also a level of simulation and adaptation. These complex properties are very important due to both the working process and the implementation of human factors. The use of new, modern, and complicated technology in the forest economy places higher mental demands on the operators.

> These demands always increase with machines of a new generation, complex production and processing lines and technological units and devices (Chang, Wang, 2000).

Morals and characters also affect the whole complex human-technique-environment system. A good working attitude depends on character. It also has a very important role in the working process, especially regarding the results of the work, as well as responsibility for the given machine, its maintenance, and cleaning. From an ergonomic point of view, an incorrect approach is when the operator is evaluated on the basis of a great work performance on a damaged working tool. One of the main criteria is the good health (physical and psychological) condition of an operator, especially their muscular condition and sensory levels. When operating forest technology, it is very important to have good sight: e.g., acclimatization to daylight conditions, recognition of mechanisms and material movements, reaction to light and shadow changes, and changes of sight in different plains and sides. The sense of hearing is very important as it provides a means of communicating with other people in the working cycle and a sense of traction, which is essential for the manipulation of a machine's remote controls. It is evident that bad health is a significant problem for human activities in the working cycle. The attitude to work and tranquillity are a result of a person's emotional condition that is affected by the work situation, as well as disturbing or stimulating agents.

It is possible to say that the basic stimulating factor is salary. There are also other factors, such as the social evaluation of work and work results, the evaluation of people in the working team, and satisfaction with work. This is very important activity for leaders, especially checking and evaluating the results.

Stimulating factors are also non-work situations and personal relationships, which can affect work situations significantly. High physical and psychological loading decreases productivity. In order to evaluate loading, it is necessary to assess working conditions and human capacity. Working conditions follow on from working tools, technologies, organization and work regimes, level of protection for workers, and so on. Worker's sensory and mental capacity will be assessed from a physical robustness point of view, as well as by considering the different physical and chemical factors at play in the workplace. It is also very important to consider age, gender, and other individual factors carefully.

> The elimination of loading and working efficiency has close relationship to long-term effectiveness of people and they are also adequate to working loading and conditions of working environment and occupational health and safety. It is possible to require the necessary performance in case when its release is not problem for physical, sensoric, psychological, and social tranquillity (Dong, Welcome, Wu, 2005).

Regulations regarding loading are connected to people's biological (women, men, teenagers, old people, etc.) and social dispositions (qualification, work experience, etc.). Loaded parts of the human body will be tired after work activities and efficacy will be decreased. Fatigue can be local (muscles, ears, eyes, etc.) or central. Fatigue is caused by physically demanding work and having to concentrate. The mental load is increased due to modern technology and as a result of incorrect ergonomic designs.

The next aspect is the adaptability of operators who work both outside and directly with a machine. Outdoor conditions can affect the body, which has to change its activities to suit an outdoor environment. Outdoor factors refer to sensory and motor functions, which are affected by fear, risky situations, and emotional demands. Working ability and reliability are required to balance the system. When designing machines and workplaces, it is necessary to consider human's ability to overtake physical limits, as well as the affects of doing too many activities at the same time, receiving too much information in a short space of time without feedback and completing precise activities in difficult conditions or under time

pressures. This is connected to brainpower, experience, specialization, qualifications, and moral properties, as well internal and outdoor working and non-working conditions.

The operator's working environment

> Regarding human character in the working process, it is necessary to apply ergonomic principles at the design of machines and devices. Recent general principles, approaches and parameters are a part of the research, development, and production of forest machines (Schwarz, Dado, Hnilica, 2011).

The operator's working environment is an important issue. It is mostly connected to mobile mechanization machines. The basic conditions for workplace layouts are anthropometric parameters, the required working position, the movements that need to be performed, visibility, and the type of work. Anthropometric parameters—human-technique-environment—are key. Anthropometry is concerned with workers' physical dimensions and the affect of different population groups on working conditions. Anthropometric data is used to design workplace machines and their individual parts. Ergonomic solutions focus on people's static and dynamic dimensions, their weight, and their maximum power in terms of lifting materials, pressing or pulling levers, pressing pedals, and so on.

The operator can sit, stand, and change their position with a machine. It is obviously possible to control the machine from one place and when in the sitting position. This is advantageous because the energy consumption is lower. It also increased the power to the pedals and the operator's stability. From a physiological perspective, it is advantageous to change positions (sitting and standing) to improve blood flow to the body.

From an anthropological point of view, this workplace requires activity from the hands, arms, legs, and eyes. There should be an optimal functional space for the arms and legs, and objects should be within reach. This is how the space is defined and this is why it is necessary to respect anthropological parameters, the recommended distances, and so on.

Cabins are the most suitable solution for modern mobile machines. This is because their construction provides a calm workspace. They should provide a working seat, and buttons and indicators should be designed ergonomically. The working seat should provide a comfortable sitting for operators, eliminate vibrations, and enable an adequate view of the mobile

machine's working parts and processed materials. Seats should also be able to move their position to suit the dimensions of the operator, the springs should be able to support various weights, and the seat should be easy to reach.

> Controlling buttons (joysticks) are one of the main factors for the efficiency and reliability of modern forest machines. Their importance grows with complexity and mechanization of the machine. In such process there is a role of people eliminated just for controlling (Poole, Elms, Mason, 2006).

Buttons, levers, manually controlled wheels, and pedals are also needed. It is necessary to consider the differences in operator habits when using the machines. Controlling buttons should be designed to control physical loading and other elements. Their placement needs to ensure that the most important data is the most. Their shape and colour is of utmost importance as they are a visual tool. The frequency of their use is another factor. Concave dashboards and sloped boards can provide solutions to some of these issues. Machines should be designed using visual analysis and attention should be paid to the question of light. It is important to have a good view of mobile machines, and a focus on their active parts. It is important to check the space around the machine. Limited visibility will affect the information available.

By following these standards, it is possible to obtain an optimal workplace setting, which considers the operator's comfort. Another important issue is access to the workplace: e.g., dimensions of steps and rails, their surface treatment, door size, and locks. From a safety point of view, it is important to have covers, which can be taken away, and lifting and maintenance issues should be considered. Safety should form a fundamental part of their construction.

The next important issue when assessing forestry machines is their operational reliability. Machines should be balanced and actively avoid overloading and injuring people. Ease of setting, cleaning, and maintenance are also integral.

Optimization of the working environment

> Current forest production is done in diversified conditions of the working environment. Operators of the mobile machines are outside in the whole production process (from growing to cutting and stocking) the whole year. Consistent implementation of modern technologies decreases ratio of

> manual physical activities of people, and it increases psychological loading of operators (Lukáč, 2003).

The mechanization of forest production has brought with it noise and vibration issues. Operators are exposed direct noise and from transferred mechanical movements. A solution to many noise problems caused is to use automation and remotely control noisy machines. The most important thing is to decrease noise and vibrations within the machine through the use of technology and construction skills. Using technology to construct the engine and seats, as well as to create insulation and acoustic modifications can help to address this. Other measures that can be taken are shorter or more diverse work hours, more breaks, using personal protective equipment, and regular medical check-ups.

The adequate transportation of operators to work is also closely connected to good levels of comfort. This is sometimes a problem of implementation in new types of production. Ergonomic issues in forestry and forest technology are much more complicated. This is the reason why it is necessary to research these issues and analyse all human-technology-environment factors to define criteria and parameters to optimize workplace solutions and to create standards and regulations. Integrating health and safety, hygiene, work psychology, anthropology, and so on helps to create optimal working conditions and decrease the risk of accidents, diseases, and other negative affects.

Design and ergonomy

> Current understanding of ergonomy comes from the system thinking which means the base for system human-machine-environment. These three elements exist in mutual interaction and dependency (Griffin, 2004).

This principle is central in the construction of new machines and devices. Here, equipment is the first thing to think about when preparing a project. Other important factors are capacity, strength, reliability, fuel consumption, dimensions of the cabin, access, view, type and position of the seat, position of the information panels, position of the steering wheel, type and position of manual levers and pedals, microclimatic conditions in the cabin, noise and vibration transmissions to the operator, internal lights, and safety requirements.

Trying to fulfil all the above ergonomic requirements can lead to non-conformity or unusual solutions. It is evident that the application of

anthropometry (body size, body movements, power of arms and legs), psychophysiology (quality of sight and hearing), hygiene (acceptable levels of noise and vibrations), and thermoregulation is essential.

Working systems and ergonomy

> People, machines, technical devices, workspace, places and factors of working environment create the whole working system (Schopper, et al., 2004).

Their roles and functions are due to social necessity and, from this point of view, there are working systems assigned for the production, transportation, information, delivery, defence, and so on. Each of these aspects has its specific parts and place certain demands on the human operator. This influences his performance, health, safety, working comfort, satisfaction, reliability, motivation, self-realization, length of time they are able to have an active life, and so on.

> Human efficacy is dependent on individual body organs, and their activity and cooperation is dependent on individual properties and on the type of work activities and tasks realized in the system (Schopper, et al., 2004).

Basic determinants of performance capacity

The basic determinants of performance capacity are as follows:

- Body dimensions, which are given by the anatomic construction of the human body: e.g., the muscles and skeleton;
- Movement and muscular power, which is provided by the mobility in the neck trunk, arms, and legs, as well as a number of interacting muscular fibres and their groups;
- Sensorial capacity: i.e., hearing, sight, and touch, and their limits regarding feeling;
- Psychological capacity: i.e. the capacity of the central nervous system to solve metal tasks, such as thinking, decision making, memorising, imagination, and so on;
- Loading tolerance: i.e., resistance to the impact of negative work conditions and environment.

Criteria for development, design and construction

The above criteria, together with the innovation and assessment of working systems, represent several elements, such as technical

requirements, preciseness, quality, reliability, economy (i.e., costs), utility, wearing, maintenance and repairs, and safety as defined by the risk of work accidents and health problems. Negative impacts on humans include, inadequate work loading, negative work system functions, and physical and chemical environmental factors that causing psychic and somatic diseases in human organs.

Basic criteria for work activities

Applying criteria to life and health protection is a part of many scientific fields of study. The most important of these criteria are as follows:

- Physiology of work;
- Work hygiene;
- Psychology of work;
- Safety of work;
- Static and dynamic anthropology;
- Working medicine;
- Toxicology, etc.

All of the scientific fields of study mentioned above have a certain knowledge basis, and use different processes and methods to find the impact of work devices and the influence of the environment on humans. They impose limits and rules; they also make statements, recommendations, and encourage legal measures, such as technical standards and laws.

Main and partial ergonomic criteria

All of the technical parts and human functions can be defined by various criteria, which should be respected in all phases of project preparation (Schwarz, Dado, Hnilica, 2011).

a) Body dimensions

- Space requirements on the workplace and work position;
- Height of the work space;
- Safety dimensions (e.g. from covers);
- Working seats.

b) Working position

- Operating parts of the machines and their placement;
- Weight and shape of loadings;

- Visibility of data sources;
- Placement of joysticks.

c) Working movements

- Ways, preciseness, speed; energetic consumption; movement stereotypes;
- Power needed for controlling joysticks; following movements;
- Visualization;
- Motoric coordination.

d) Getting and processing data

- Types and position of sight information;
- Way of information coding;
- Sources and placement of direct information sources;
- Types and properties of sound information;
- Voice communication;
- Controlling, regulation and decision taking processes.

e) Physical, chemical, and biological properties of the working environment

- Noise, ultrasound, vibrations;
- Light;
- Colour solution of the environment and machines;
- Places without a daylight;
- Radiation;
- Chemical substances in the air;
- Microclimatic conditions;
- Air circulation, air conditioning.

f) Work safety

- Safety protection (e.g. covers);
- Personal protective equipment.

g) Work organization

- Working regime and relax during work shift;
- Periodicity of shifts;
- Cooperation in work teams;
- Series and mass production;
- Limits for work loading.

Ergonomic requirements are met through the technical standards provided in guidelines issued by the European Union. Questions of safety and health protection in interaction with ergonomy are necessary to implement the research, design, and construction of forest machines. It is necessary to pay attention to this topic in order to create a deep analysis of all the

necessary factors; this will allow us to define the criteria and parameters for optimal solution to various working conditions. This way it is possible to create adequate technical standards and regulations.

Vibrations and noise: EU standards and regulations

New EU regulations ensure machine safety. They meet the legislation for both Slovak and other member states. They are required to implement completely new ideas, as well as modern approaches to solving technical and ergonomic issues. Issues with regard to the safety of operational machines and devices are closely connected to ensuring the occupational health and safety of operators at work. These issues are increasingly part of business strategies and companies are realizing that they have to take precedence over economic interests. The Slovak republic accepts and implements both international and European technical standards. Measures are taken which eliminate harm and danger, particularly with regard to the operator´s health. Additionally, dangers can occur in non-standard situations but they can mostly be predicted.

European Union legislation

European Union legislation has two stages. The first stage consists of European Union directives, which indicate the general requirements for safety and work organization. The second stage involves the European standards that define risk factor parameters within working environment (e.g. vibrations, noise, light, dimensions and position of workplaces for operators, controlling elements and requirements for available information). The requirement for applying ergonomic rules and principles is given European Union directives and standards (e.g. EN or ISO). They aim to unify all aspects of all workplace safety and to eliminate overloading the operator.

The effect of vibrations and noise on an operator

Human anatomy is very complicated. There are many degrees of freedom with linear and non-linear elements and some of them have significant resonance properties. The significant ergonomic risk factors are low frequency vibrations on the human organism (acceleration of mechanical oscillation), noise from controlling elements, and the contact areas between an operator and a machine. On the basis of these risk factors, hygienic standards and safety regulations were created that define the

maximum acceptable vibrations in different frequency areas (vertical and horizontal), noise limits (emissions and imissions) and exposure times. Regulations and standards of safety work for mechanical oscillation are shown in Fig. 2.1. Safety regulations and standards for noise are shown in Fig. 2.2.

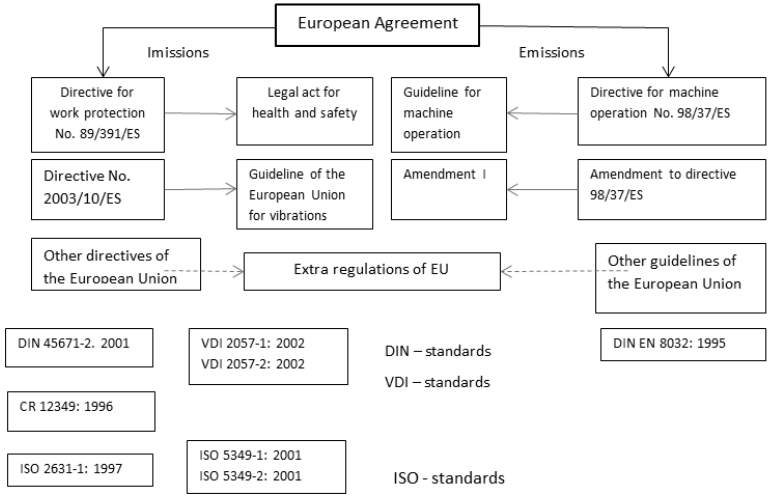

Fig. 2. 1 European Union regulations and standards of safety work for mechanical oscillation (vibrations) *(Kučera, Urblík, 2002)*