LED Lighting Interviews and Assessment in Forest Machines

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***Abstract*—**The objective of the study is to assess the implementation of LED lighting into forest machine work in the dark. In addition, the paper includes a wide variety of important and relevant safety and health parameters. In modern, computerized work in the cab of forest machines, artificial illumination is a demanding task when performing duties, such as the visual inspections of wood and computer calculations. We interviewed entrepreneurs and gathered the following as the most pertinent themes: (1) safety, (2) practical problems, and (3) work with LED lighting. The most important comments were in regards to the practical problems of LED lighting. We found indications of technical problems in implementing LED lighting, like snow and dirt on the surfaces of lamps that dim the emission of light. Moreover, service work in the dark forest is dangerous and increases the risks of on-site accidents. We also concluded that the amount of blue light to the eyes should be assessed, especially, when the drivers are working in a semi-dark cab.

***Keywords*—**Forest machines, health, LED, safety.

I. Introduction

MECHANICAL forest harvesting is an important working task in Finland and in other Northern Countries. In the winter, most mechanical forest harvesting has to be done in the dark. Lighting and the ability to see and be seen properly are therefore of utmost importance. There are about 2500 forest machines working in Finland, which are operated by 4000-8000 workers. [10]

Early LEDs came to practical use in 1960s, and they were often used as indicator lamps for electronic devices, replacing small incandescent bulbs. Recent developments in LEDs permit them to be used in environmental and task lighting. Light-emitting diodes are now utilized in applications as diverse as aviation lighting, work and automotive headlamps, advertising, general lighting, and traffic signals. The most popular LED lighting product, a phosphor-conversion (PC) LED, is an LED chip that emits blue light, which passes through a yellow phosphor-coated layer to generate the ultimate white light [9], [13], [16], [17]. LED lamps are usually deemed to be safe in terms of radiation emissions. IEC 62471 was officially adopted by the European Union as EN 62471 in 2008; thus, all new products with a Conformité Européenne (CE) label must indicate potential optical hazards with appropriate labels, if applicable [3]. Labeling is currently voluntary in most other countries, including the United States. LED products are no more hazardous than other lighting technologies that have the same correlated color temperature (CCT). Furthermore, white-light products employed in general lighting service applications are not considered a risk for blue light hazard according to current international standards. Sensitive individuals may have additional concerns and colored light sources—which may be classified as Risk Group 2 or higher and require a label to meet accepted standards-should be evaluated on a case-by-case basis.

Not until recently have LED lamps reached a stage of development where they are efficient enough to be implemented in the lighting systems of forest machines (Fig. 1).

Fig. 1 Example of a forest machine

The problems with LED lamps concern producing white light and concentrating the light into a beam or spreading it out evenly. The advantages of LED lamps lie in luminous efficacy, size, lifetime, and shock resistance, while disadvantages include high price, temperature dependence, voltage sensitivity, light quality, and, in some cases, the tendency to attract insects. For comparison, oil lamps, incandescent light bulbs, and xenon lamps have a luminous efficacy of 0.1 lm/W, 15 lm/W, and 90 lm/W, respectively, while LED lamps can produce 300 lm/W. Moreover, incandescent light bulbs typically rated as having 1,000–2,000 hours of useful life and xenon lamps 2,500 hours, whereas a LED lamp can last up to 40,000 hours. This gives LED lamps a competitive edge.

In Finland, lighting conditions are often assessed against the indoor lighting recommendations of the Illuminating Engineering Society of Finland (SVS 1986) as well as the standard EN 12464-1 [4]. The standard specifies lighting

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levels both for the task area and the immediate surrounding area. It is recommended that, in the case of a forest machine, the operating area of the crane should be illuminated to 60 lx, the periphery to 15 lx, and the harvester head to 120 lx. The driver's vision should extend 25 m upwards at a distance of 10 meters. Another important parameter in lighting is illuminance uniformity that is the ratio of the lowest to the average illuminance between the task area and the immediate surrounding area: although the average illuminance may be appropriate, a non-uniform illuminance (common during the night, especially with snow) may causes several problems, including relevant safety problems.

The aim of the paper is to assess the implementation of LED lighting into forest machine work in the dark. We show that this means considering a wide variety of safety and health parameters. In modern, computerized work in the cab of forest machines, artificial illumination is a demanding problem like the visual inspections of the wood and computer calculations. We briefly present here the main risks possibly related to the introduction of LED lighting in forest machines, and the results of an interview in a group of driver entrepreneurs.

II. LED Interviewed Lamps and Health Issues

Light-emitting diodes (LEDs) emit higher levels of blue light than conventional light sources. From an environmental health perspective, retinal light injury and the potential risks for chronic exposure from using LEDs as a light source require assessment. LED (or solid-state) lighting sources are designed to emit all energy within the wavelength range of human vision. However, many current “white-light” LED designs emit much more blue light than conventional lamps, which has been suggested to have a number of health implications, including disruption of circadian rhythms [7]. Although the white light generated from LEDs appears normal to human vision, a strong peak of blue light ranging from 460 to 500 nm is also emitted within the white light spectrum; this blue light corresponds to a known spectrum for retinal hazards [2]. Some epidemiological studies have suggested that short-wavelength light exposure is a predisposing cause for age-related macular degeneration (AMD) [17]. Animal models have also been used to determine that excessive exposure to blue light is a critical factor in photochemical retinal injury targeting photoreceptors and retinal pigment epithelium (RPE) [5].

Artificial light can affect regulating human physiology and behavior and can therefore alter human physiology when inappropriately timed. One example of potential light-induced disruption is the effect of light on circadian rhythms, including the production of several hormone rhythms [6], [15]. Changes in light–dark exposure shift the timing of the circadian system such that internal rhythms can become desynchronized from both the external environment and internally with each other, impairing our ability to sleep and wake at the appropriate times and compromising metabolic processes. Light can also have direct acute effects on neuroendocrine systems, for example, in suppressing melatonin synthesis or elevating cortisol production that may have untoward long-term consequences. There is limited but thus far generally consistent evidence in support of the hypothesis that altered lighting can play a role in breast cancer etiology [1], [6], [15], and there is growing interest in a lighting and/or sleep connection to other conditions, such as prostate cancer [8], obesity [12], diabetes [11], and depression [14].

Certain amounts of LED light exposure have suspected to induce retinal damage. When analyzing blue-light hazards, we cannot exclude the risk of chronic effects from daily exposure because photochemical damage may not induce an acute syndrome; instead, blue light exposure may cumulatively induce photoreceptor loss. Regardless of whether the initial damage is caused by a photochemical effect, LED light damage is dependent on wavelength and duration. Nevertheless, in the evaluation of possible health risks in forest machine drivers it should be considered that in case of a direct vision of the source, the spectrum of light arriving to the retina is strictly related to the spectrum emitted, but in this case most of the light is reflected from surroundings (snow, leaves, soil, etc.): the reflectance of different wavelength is not uniform, so also the wavelength of the light reaching to the retina can vary depending on reflection. But one of the main problems to be considered in these workers is the risk related to poor lighting conditions, as non uniform luminance: this does not directly harm the eyes, but it does increase the risk of accidents (e.g. in case of dark areas, or also of glare in visual task area) as well as of fatigue at work. Prolonged focusing of the eyes near or at a certain distance, with static loading on the eye muscles, but also the need of continuous adaptation to different lighting levels and glare may cause eye strain (and, in some cases, possibly also afterimages) [18]. It is, therefore, important to give rest to the eyes from time to time. The association between the stroboscopic effect and symptoms, such as headache and epileptic seizures, has been studied for a long time but with few unambiguous conclusions. Another potential risk is chemical: LED lamps contain and, if broken, may release hazardous metals, but in normal operation, they do not produce any toxic fumes.

III. Materials and Methods

The interview of the entrepreneurs was based on several areas of health and safety (Fig. 2). The interview included the following topics: (1) safety, (2) practical problems, and (3) work with LED lighting.

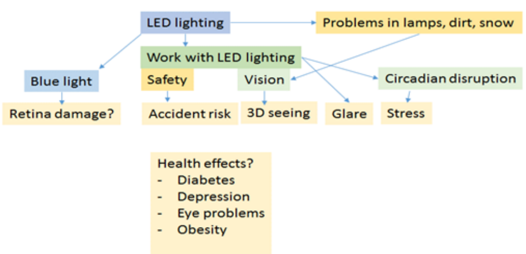

Fig. 2 Parameters of Intensive LED lighting and health in the dark, e.g., work with forest machines

The use of LED lighting is a new concept in forest machines; therefore, currently, it is only possible to interview the entrepreneurs.

IV. Results

In interviews with the entrepreneurs (n= 5), the inability to melt snow build-up on the surface of the lamp and the subsequent deterioration of lighting conditions, as well as poor long-distance (5–20 m) illumination, were cited as drawbacks of modern LED lamps.

A. Examples of the Working Environments

Fig. 3 shows the working environment of the Finnish forest machine in the daytime, and Fig. 4 shows the working environment in the evening.

Fig. 3 Working environment of Finnish forest machine in the daytime

Fig. 4 Working environment in the evening

B. Comments from Entrepreneurs

Highly reflective snow fields and dark rainy nights in the fall were seen as the most challenging outdoor conditions. Another challenge seemed to be that objects appearing in bright light from an LED lamp may cause glare and reduce vision. On the other hand, the long lifetime of LED lamps compared to, for example, xenon lamps, was expected to bring benefits.

In the cab of a forest machine, with a limited amount of light, there are objects that need to be seen distinctly, such as switches, instruments, and a computer. Visibility can be further reduced by light reflected by windows, reflections, or sharp shadows created by work lights positioned outside of the cab. Hence, in terms of vision and lighting, a cab environment is a likely place to experience eye fatigue.

Night work and related physiological fatigue can be other contributing factors. Seeing distinctly is not possible in poor lighting. Moreover, it takes time to adjust to changing lighting conditions. The eyes of a person with nyctalopia can only adapt to a certain level of darkness. This can be a major issue when working with a forest machine combining bright, glaring lights outside on the boom and the cab, a limited amount of light, and objects that have to be seen. In some people, lack of light may induce depressive symptoms, such as fatigue, low mood, and increased appetite.

V. Discussion

Work with forest machines in the dark is a demanding task. A prerequisite for seeing clearly is the ability to maintain a sharp image in the sharp vision area of the retina. Other crucial factors are coordinated eye-head movement towards the target and the ability of the eye to adjust its focus length as required. The eye works best in conditions where all the wavelengths of light are represented in the right proportions. Unfortunately, the photographs herein present only summer conditions (Figs. 3 and 4). The most challenging environment occurs in autumn, winter, and spring. The wintertime is the best time to utilize those machines because then the terrain is frost, which minimizes damage to the land.

So far, no serious adverse health effects have been presented, but as always, there are suspicions and doubts of possible harmful effects. Epidemiological research should be conducted to determine if any of these concerns are founded. However, this would require an international study because forest machine workers are too small of a group.

The more complete the color-spectrum of the light, the more comfortable it is to the eye, hence reducing the risk of fatigue. Aging affects vision, with 60-year-olds having an average visual acuity of half of that of 20-year-olds. Furthermore, the optical power reduces from over 10 diopters at age 20 to 1 at age 60. This means that to get the same visual impression as at age 20, illuminance needs to be multiplied by 12 at age 60. There are few cures to address the effects of aging, other than glasses and better lighting.

Good lighting can cut the rate of errors down to half. The effect of increased illuminance on productivity is more prominent in aged workers than in younger ones. For reasons of adaptation and risk of accidents, when comparing work stations where the same tasks are performed, the level of illuminance at a work station with the poorest lighting should be more than 70% of that of the work station with the best lighting.

Likewise, in outdoor tasks, a reasonable level of lighting is often required to prevent the risk of accidents and simply to allow seeing. A large number of accidents, even fatal ones, occurring during outdoor work can be attributed to an inadequate lighting, including (but not limited to) insufficient luminance, non-uniform illuminance and glare. Appropriate outdoor lighting facilitates seeing and makes work possible. When moving around on sites with forest machines in operation, CE-marked, high-visibility clothing with an adequate quantity of fluorescent and retro reflective material should be worn. A flashlight can also be a useful aid for visibility and vision.

Aging and dirt build-up reduce the level of illuminance produced by lighting equipment. Lighting should, therefore, be designed to give a level of illuminance higher than the recommended level. The maintenance factors to be taken into account in lighting design are determined by the maintenance plan and expected dirt accumulation, among others. Dirt build-up should be considered when preparing a maintenance plan and determining service intervals. Increasing the quality of lighting is one of the most affordable ways to improve a work environment.

So far, there have not been any health suspicions concerning forest machine workers. Certainly, there have been workers who have left this occupation because they could not tolerate night or shift work. Moreover, for persons whose vision is not good or if their 3D vision is lacking, it is very hard to work in this profession. Good and regular vision examination is also necessary. Therefore, it is important to further study LED lamp problems and the health and safety of forest machine workers.

VI. Conclusion

Thus far, there have not been any significant adverse effects to health and safety for the forest machine workers while working in the dark. The amount of blue light to the eyes should be assessed, especially, when working in a semi-dark cab. There are indications of technical problems in implementing LED lighting, like snow and dirt on the surfaces of lamps that disturb the emission of light. Service work in a dark forest is dangerous and increases the risk of accidents.

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