WORK SECURITY AT INDUSTRIAL ULTRASONICS APPLICATIONS

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ABSTRACT: Using of ultrasound in various applications can represent a serious risk to health. The paper presents the comparative range of ultrasound main active applications in industry, but also an overview of the effects of ultrasound on the biological systems, system components in terms of employment, having in foreground the human operator. Some practical rules applicable in the various stages of the life cycle of ultrasound equipment are presented. Because of the diversity and complexity of installation it will be taken into consideration the relationship between the risk factors and the preventive measures but also the safety labour measures.
KEYWORDS: ultrasonic applications, health and work security, risk factors, preventive measures.

1. GENERAL CONSIDERATIONS

An important aspect in applying nonconventional technologies is the activity of prevention, minimizing the risk of accidents and professional diseases. Along the development of ultrasonic applications in various fields, their effects on the operating personnel and the environment have been studied. In the first section, the paper proposes a systemic approach on the current interest in industrial applications of ultrasound. The second part presents an overview about the risk factors and the prevention measures in the analysed field.

2. ULTRASOUND APPLICATIONS

The dynamic of top areas of current technologies is conditioned by the development of technical systems based on concentrated energies. Among them an important place has the ultrasonic energy. Figure 1 presents the frequency range corresponding of ultrasound [1],[2],[3].

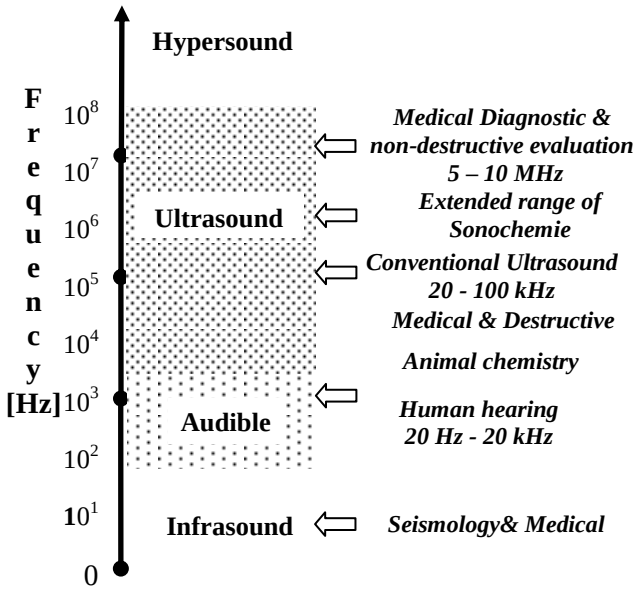

Figure 1. The frequency range of ultrasound ([1,2,3])

The ultrasounds have wide applicability due to their particular characteristics [4],[5],[6],[7]:

- have relatively short wavelength;
- the particle acceleration of vibrated environment can reach up to 10^5 g (g - gravitational acceleration);
- allow directing ultrasonic beam in inaccessible places for other machining processes by focusing concentrators acoustic energy using devices like horns and waveguides;
- enable common materials processing, but especially enable the processing of hard materials or other materials that are impossible to be machined by classical machining.

In the literature it is shown that if through a work medium is propagate ultrasound oscillations with different frequencies and amplitudes, are reached the phenomena of interaction with the internal network of material and the defects of the network, which leads to a more or less absorption of acoustic energy. Figure 2 presents the ultrasonic oscillation amortization according to their amplitude [4],[7]. There are several time intervals:

- *domain* I – typically for very small amplitudes; it doesn't cause any permanent deformation of the medium which ultrasound is propagated in; there are only small losses by absorption;
- *domain* II – there is a linear dependence of attenuation of the ultrasound in ratio with the amplitude;
- *domain* III – the attenuation is time dependent and is attended by irreversible deformation of the medium.

According of these characteristics of ultrasound and the way the ultrasonic energy comes in different operating processes wherein it is used, the ultrasonic applications can be grouped in two big categories:

- *active or technological applications* – the used ultrasonic energy is big enough to produce changes

in the medium structure wherein it diffuses. The ultrasound has an active role by performing mechanical work or as an accelerator agent of the conventional machining processes.

 passive applications - The ultrasound with a quite low intensity can't produce structural changes, but gives information about the property, quality or dimension of the examined object.

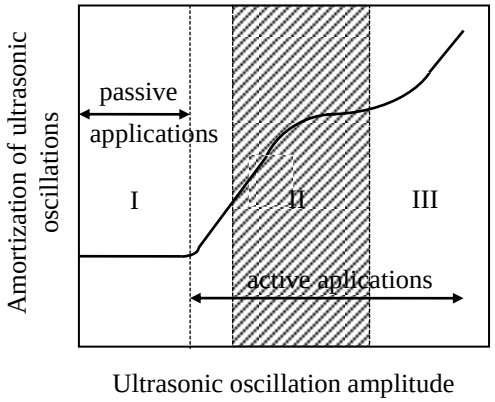

Figure 2. The domains of application of ultrasound depending of their amortization [4],[7]

With all the advantages of ultrasound determined in the laboratory, justifying the extension of industrial ultrasonic waves application, especially for reasons of economic profitability, only a fraction have shown a higher industrial prevalence [7],[8]. In the literature there are a lot of references related to the effects of ultrasound on gaseous, liquid and solid medium. Research up to now, targeting especially:

- for active applications: the field of dimensional ultrasonic processing, ultrasonically aided classical machining: turning, drilling, grinding, finishing and superfinishing processes; plastic deformation: deep-drawing, wiredrawing; plastics and metal welding, mounting inserts; ultrasonically aided nonconventional machining such as electro discharge, electrochemical and laser beam machining; metallurgical processes: casting, heat treatment; ultrasonic cleaning, activating various liquid media or the physical-chemical processes etc.
- for passive applications: non-destructive defectoscopy, measuring different physical or geometrical magnitudes etc.

Figure 3 [8] presents topical areas of technological applications of ultrasounds, development trends, coverage and assessment cost – complexity. Among active applications of ultrasound, compared to other ultrasound techniques, the priority in the industry has the ultrasonic welding, cleaning and activation of liquid media.

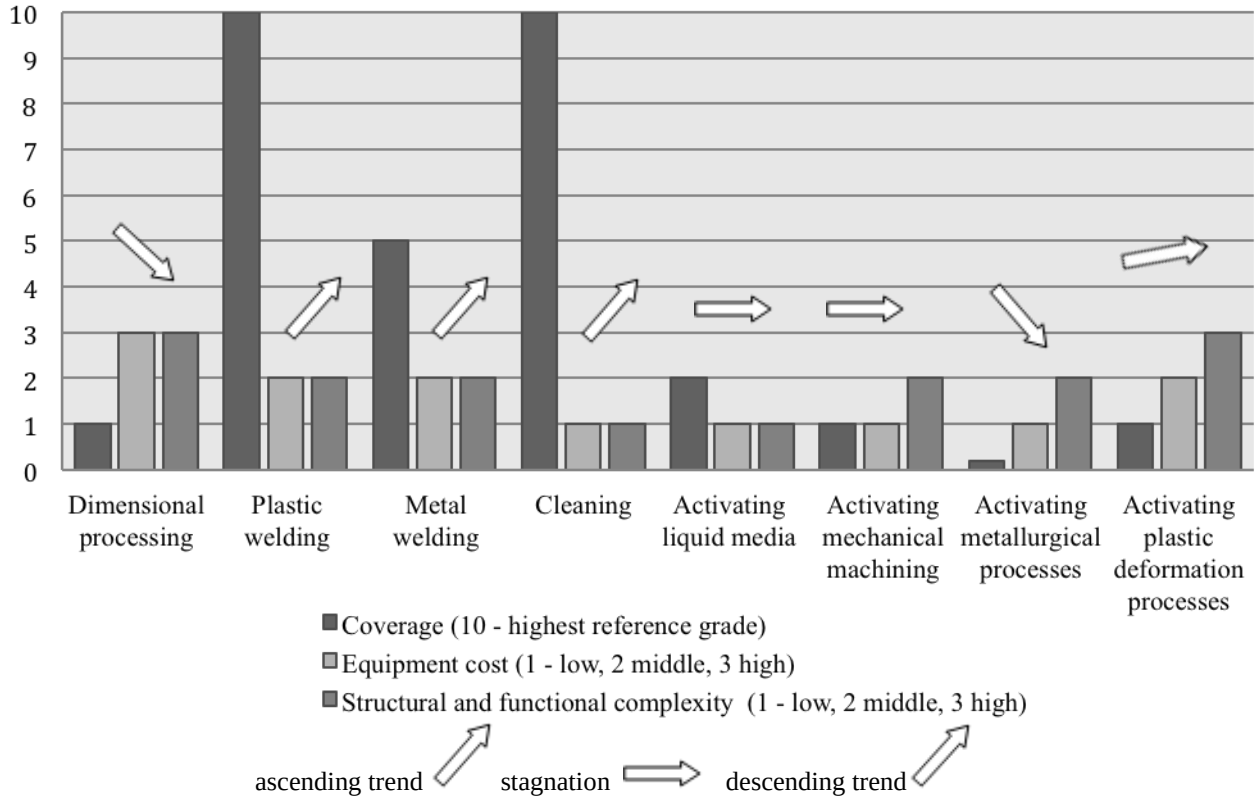

Figure 3. Current trends in active applications of ultrasound in industry [8]

3. ULTRASOUNDS – BIOLOGICAL EFFECTS

The passage of ultrasound by biological systems may occur either biopozitive and bionegative effects or does not produce any kind of changes [9]. Depending on the exposure time, ultrasound irradiation may be incidental, in the case of the diagnosis or therapy with ultrasound or permanent, in the case of persons working with ultrasonic generators for different types of applications. Thus, the main factors influencing effects of ultrasound on biological systems [9],[5],[4] are:

- ultrasound exposure parameters: frequency, intensity and acoustic power, pulse duration etc.;
- the environment through which it makes the transmission of ultrasound: solid or fluid transmitter.

Depending on these parameters there are:

Biopozitive effects: destruction of bacteria, viruses, hence applications in sterilization of medical objects (needles, syringes).

Bionegative effects: at the personnel who work daily with ultrasound devices have been observed following symptoms: destroyed red blood cells, producing migraines, nausea, vomiting, excessive tiredness, headaches, loss of balance, muscle coordination disturbance, hyperthermia, temporary or permanent loss of hearing.

Insignificant or no effects: exposure to lower parameters, when ultrasound does not have a harmful action on the human body. Medical practice has shown that ultrasound is more sensitive to tissue differentiation compared to the radiation X and that is less harmful to the body, compared to these. Medicine currently uses ultrasonic waves in diagnosis and therapy.

Thus it has been found [9][5][4]:

- airborne ultrasonic oscillations are less harmful to human health than acoustic oscillations in the audible range, at the same acoustic intensity;
- with the increase of oscillation frequency, the attenuation characteristics in air per unit length also increase and, from this point of view, the ultrasonic radiation are less dangerous;
- cavitation is highly destructive for living organisms due to the chemical, mechanical and thermal effects generated during the cavitational implosion, and is usually accompanied by the mechanism of stress. If in some industrial applications, cavitation is essential, for living organisms, the appearance of cavitation is an undesirable phenomenon.

The biological actions of ultrasound vary depending on the characteristics of ultrasounds and the nature of the tissue exposed. Generally, every biological tissue, having physical characteristics that arise from the histological structure, has a specific attenuation of ultrasound (figure 4 [2]).

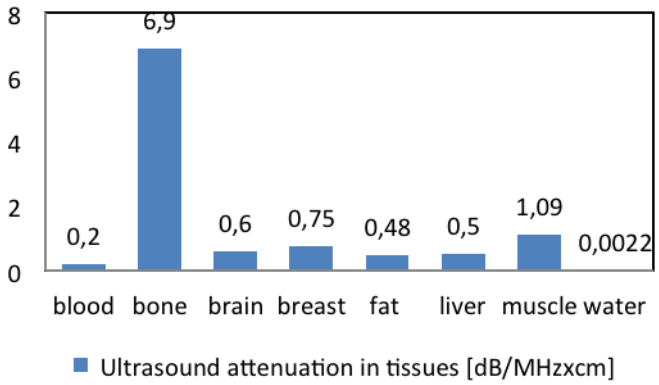

Figure 4. Ultrasound attenuation at frequency of 1 MHz to the biological tissues [2]

The ultrasound action may be general, exposing the entire body, or local, affecting only certain organs or systems. The literature describes the ultrasonic action of on the auditory organ, nervous, endocrine and muscular system, blood, skin etc. Technical documents published internationally include biological limit values for exposure [1],[10],[11],[12].

4. WORK SYSTEM FOR ULTRASONIC EQUIPMENT OPERATOR

The aim of technologies, devices and equipment able to operate with concentrated energies is increasing productivity and product quality, enhancing the performance of different types of devices in various areas of human activity. However, they must not affect the labour safety and hygiene and to not be harmful to the environment [2].

Accidents at work and occupational diseases are the result of dysfunction within the work system due to the existence and manifestation of injury risk factors. Risk factors can be found in each element of the system work (figure 5) [13],[14],[15].

Minimize the risk of injury and occupational diseases is obtained by applying of labour protection measures (table 1) [13],[16]. These are technical, organizational, hygienic-sanitary ways for the achievement of human security in the work process by eliminating, avoiding or diminishing the action of risk factors on the human body [13].

✓ measures to prevent the occurrence of risk are occupational protection measures through the application of which is removes the risk factors of accidents and professional diseases in the workplace or the substrate causative factors.

✓ protective measures against risks of accident and occupational diseases are labour protection measures by which it avoids or diminishes the risk factors action present in the workplace that can affect the operator body.

Technical measures aim in particular the operator and the work task. Organizational measures aimed the means of production and work environment. Actions involving removal or isolation the hazard aimed, in particular, the means of work, namely technical equipment.

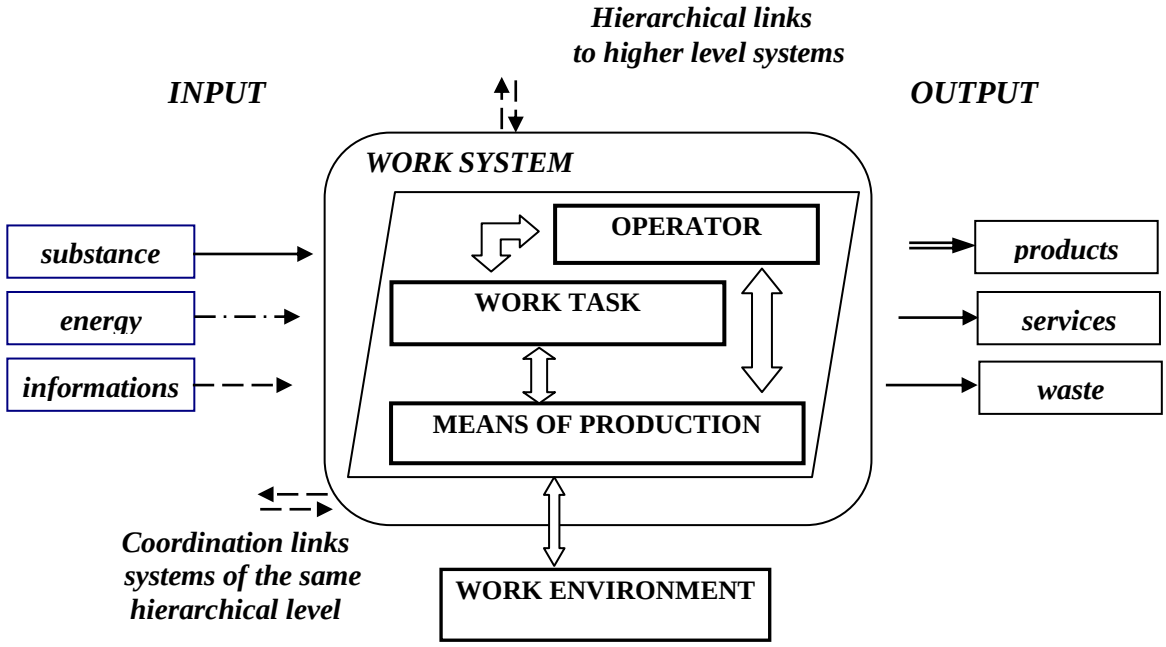

Figure 5. The entries-output general model for the workplace system [13],[14],[15]

Table 1. Inter-relationship of risk factors – prevention measures [13, 16]

HUMAN SECURITY IN THE LABOUR PROCESS	
RISK FACTORS	***PREVENTIVE MEASURES***
OWN OPERATOR *Wrong actions:* Carrying out improper working operations Doing operations outside the work task Communication with risk of accident *Omissions*	Staff selection Training, information, documentation, awareness Preventive control Individual protection equipment
OWN WORK TASK Content and structure inadequate for the purpose of the work process or risk situations Requirements under / oversized imposed to the operator in relation to its possibilities	Ergonomic work organization Determination of work task Optimum coordination of activities
OWN MEANS OF PRODUCTION Mechanical risk factors Thermal risk factors Electrical risk factors Chemical risk factors Biological risk factors	The conception of non-hazardous technologies with low risk Collective protection devices Ergonomic organization of the workplace
OWN WORK ENVIRONMENT Physical risk factors Chemical risk factors Biological risk factors Psychosocial factors Special character of the environment	Providing industrial ventilation installations Standard equipment and devices to combat chemical pollutants, noise, vibration, radiation etc. Providing lighting installations

5. SAFETY CONDITIONS FOR WORKPLACES EXPOSED TO ULTRASOUNDS

At workplaces using ultrasound equipment is difficult to delimit only the ultrasound effect in relation to the synergic action of the process factors. In order to optimize the prevention of occupational accidents at work and work diseases it must analyses all the risk factors of each element of the work system and respect at every level of safety rules. In table 1 have been tagged the general risk factors apply to a workplace. Anyone who designs, build and use these equipment must be aware of the effects of electric currents on the body and take all measures to exclude any risk from using their current activity (figure 6, [17]).

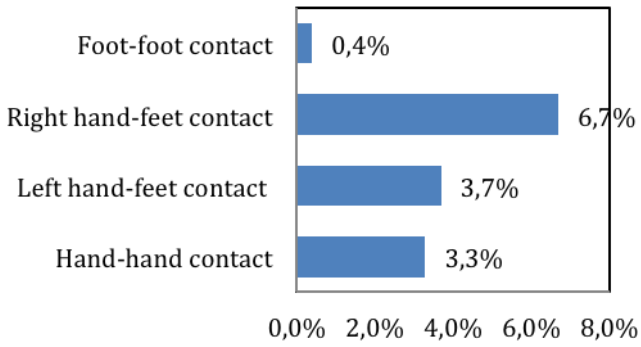

Figure 6. Severity of the accident by electric current path [17]

Major danger by electrocution occurs, in most cases, by the electric current effect on the heart and only in minor proportion by burns or paralysis of the respiratory muscles. For the same overall risk taken by a subject, the risk depends on the proportion of the current which passes through the heart, caused by the contact points.

In the analysed context of the ultrasound application, apart from general factors, it should be specify the additional risk factors, specific to the workplaces that using ultrasound equipment [18],[19],[20].

Factors related to the operator: as in the case of exposure to noises or vibrations, there are predisposing factors of which depends on the ultrasound action on the human body: individual susceptibility, hearing diseases, age, sex, smoking and alcoholism.

Factors related to the means of production. It can be made by grouping them in relation to:

- structural elements specific to ultrasound equipment; improper exposure parameters
- factors related to the process itself.

Factors related to the working environment: simultaneous exposure and other risk factors.

Thus additional measures are taken specific to these workplaces [9]:

- ultrasound generator and the ultrasonic block will be connected to the ground;
- it will check, periodically, the insulation of the connecting cables from the generator to the transducer installation;
- It will check, periodically, the ultrasonic block: ultrasonic transducer and horns, to ascertain there are no cracks;
- during the process it is forbidden to touch the ultrasonic horn - especially at higher power of 250W;
- maintenance of system and any possible interventions will be made only by qualified and trained personnel;
- will ensure the effective insulation of all parts of the equipment that may spread ultrasound into the work area; the components of the equipment that have to be operated by hand during operation thereof, shall be effectively insulated against the transmission of ultrasound;
- where the equipment is fitted with oscilloscopic system for tracking ultrasonic energy, will ensure viewing conditions thereof, so as not to cause tension visual functions.

The use of ultrasound equipment raises a lot of important issues for both operator safety and environmental protection. There have been numerous studies of possible limitations of ultrasonic regimes recommended for different types of applications [9],[19],[20],[21],[22]. Effects of ultrasound can be avoided through compliance with the following protection measures [5]:

- occupational exposure to high intensity ultrasound, with sound pressure value of 110-115 dB and frequency over 20 kHz, should not exceed 4 hours per day; the maximum permissible value propagation in air is 120 dB and the acoustic pressures greater than 180 dB can produce human death;
- the operators will be able to avoid direct contact with high-intensity ultrasound waves generated in the water;
- when needed it can be reduced the noise levels from ultrasonic installations through constructive measures: using sound-absorbing materials, insulating boards etc. or, when they are not sufficient, by properly equipping the operating personnel;
- protective equipment consists of helmets with glass wool for hearing system and glasses made in Plexiglas to reduce the risk exposure of the eye to ultrasonic radiation;
- using ultrasonic cavitation applications are always accompanied by characteristic cavitation noise, and if it becomes very strong are

recommended to remove the sources that generate harmonics in the audible range or to use the Plexiglas insulation foils.

- ultrasound equipment must be provided with protection against hazardous incidents actions or wrong orders. The effects of temperature, humidity and atmospheric pressure must be reviewed and reduced, or removed if it is possible. Failure of these types of equipment is an imminent danger to the operator.

Factors related to the process itself. Consider a common application (figure 7) such as ultrasonic welding of plastic materials: polymers and / or reinforcement polymers, where arise additional problems related to [20]:

- exposure to decomposition processes of polymers, smoke, as a product of pyrolysis has various toxic components potential exposure to small fibres;
- dust and safety issues related to the process.

All these requires proper ventilation, proper control of the process, avoiding enclosed spaces.

Figure 7. Ultrasonic welding equipment for plastic materials

6. CONCLUSION

The main criteria for selection of equipment according to the main parameters taken into account [22],[23],[24] are:

Cost: ultrasound equipment should be available at a reasonable price;

Quality: ultrasound equipment should give high-quality parameters;

Safety: ultrasound equipment should be safe to use and not harm to operators.

Safety in the use of ultrasound equipment resulting from compliance of three conditions:

- Using devices of very good quality and safe;
- Fulfilment of all prescribed indications concerning facilities that ensure their proper functioning;
- Competent exploitation by trained and authorized personnel.

The requirements are formulated apart the other categories of equipment. Given the multitude of negative effects of ultrasound on human action at work, an effective medical prophylaxis performed by occupational health services, along with the use of appropriate protective perspective is beneficial for workers exposed to ultrasound.

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