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An innovative solution to vibrations in the working environment

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Abstract

Vibrations in the working environment represent a certain danger for the employee and the fact that a certain part of his body, the hand or the whole body is exposed to mechanical oscillations and tremors of solid bodies. Diseases from vibration can include diseases of the bones, joints, muscles, blood vessels and nerves of the limbs. In the case of exposure to general vibrations, these always represent systemic effects for a person - i.e. j. they affect the whole organism with health consequences in different forms and degrees. The paper deals with the innovative technical solution of the vibrating plate.

Keywords

Innovations, working environment, vibrations, technical solution, vibrating plate

I. Introduction

Human is important and the most vulnerable element of ergonomic system. Micro ergonomics which is focused on work and workplace occupies with interaction of wide spectrum of environmental factors. According to statistics of hazardous work in Slovak Republic is the noise in the first place and the vibrations in the fourth place from all of physical factors affecting to workers. Vibrations influence on physical stress of workers and they can have unfavourable after-effect on health, performance and working well-being. According to the method of musculature straining the vibrations cause the stress:

- dynamical (isotonic) stress – it happens to alternating stretching and shortening of musculature group,
- static (isometric) stress – it means the stress when the musculature is not shorted but it is changing the internal strain of its; it requires the higher effort and longer time which is needed to recuperation of organism as dynamical stress,
- combined stress. [1]

Subject of article is evaluation of vibrations affecting to hands and by manipulation to devices. This activity is very hazardous and thus after the determination of risks it is necessary to find possibilities for elimination of theirs. One of solving is possibility of commercially manufactured devices modification by redesign. In this article it will be mentioned technical modification in vibration plate.

II. RISK management causing vibration on hands and physical activity

They are used technical and organization methods or combination for reducing the vibration stress in workplace. To organization methods, it is possible to assign to Job – Rotation which used targeted change of time exposition in environment or change of worker´s activity and the target is influencing of final exposition of vibrations. Some employers develop the system of "traffic lights" – green – yellow – red in collaboration with producers and suppliers of devices. In this system, it is unequivocally marked every tool by coloured coding of vibrations on hands and shoulders depending on presumptive force of device vibrations in use. One of example of this coding scheme is in Table 1.

Workers complete the training about scheme of coloured coding in order to they can choose vibrate tool and they know how long it can use. [2] The using of "green" device indicates that exposures are probably under the action or limit level of exposure.

It can mention numerous examples of literature references to technical methods of reducing technological vibrations. [4]

Table 1 Example of traffic lights (coloured coding) – using of devices which cause vibrations on hands

Coloured coding	**Time to reach**	
	AHV (2.5 $m.s^{-2}$)	LHV (5 $m.s^{-2}$)
red	less than 30 minutes	less than 2 hours
yellow	30 minutes to 2 hours	from 2 hours to 8 hours
green	more than 2 hours	more than 8 hours

Note to Table 1:
AHV – action value of vibrations "a" [$m.s^{-2}$],
LHV – limited value of vibrations "a" [$m.s^{-2}$].

Syndrome of vibrations affecting to hands and shoulders has influence to social and family life by its health results. It is caused by vascular disorders which result from irritation of upper nerve-ending for pressure, touch and pain it is transmitted to the muscles, joint and nerve-ending of inner organs. It puts emphasis on size of upper extremities surface which are in contact to equipment (tool or device) generating the vibrations.[4]

Just this contact hand – device is important element in redesign of devices. Redesign of devices or tools presents their modification as one of possible solving for risk elimination. Algorithm of risk management is presented in Figure 1.

Reducing of vibrations is possible with construction modification for increase of exposition working time with tool and devices which cause vibrations transmitted to hands. Value reducing of vibration acceleration "a" is possible not only with personal protective devices (gloves) but also with construction modifications in device. These modifications are suitable within rationalization of works from workers themselves. Ergonomic rationalization enables for workers in manufacturing company.[5]

- Weaknesses specification of original technical solution of commercially manufactured equipment (machine) or tool by the worker himself who operates it.

- Projecting ergonomically acceptable technical solutions – equipment (machine) modification to be more suitable and individualized for the needs of the worker, e.g. handling the possibilities within the interaction of hand – machine.
- Technical improvements designed by workers are often simple and undemanding, hence realizable and verifiable even at the workplace.
- Ergonomic rationalization is important even for the movement of improvements, creation of utility models or patents that increase the company image.
- Rationalization acts benefits can be verified – for instance by measuring the decrease of vibration acceleration "a" (ms^{-2}) before and after the machine modification. Such an example is listed in the following chapter.

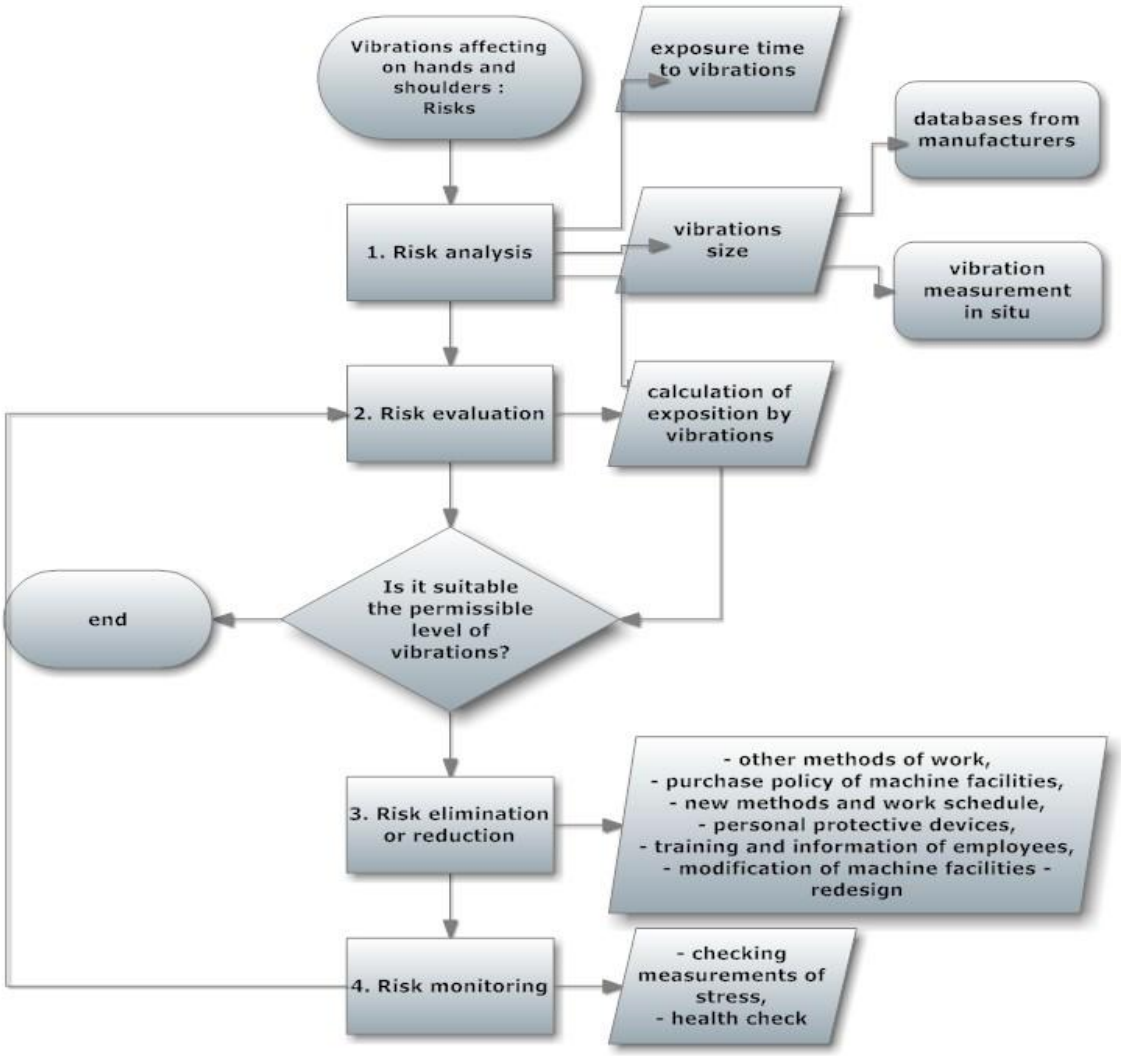

Fig. 1 Risk management algorithm of vibrations to hands interaction

It is necessary to ensure the consideration of risks in the first case for risk management in manipulation with device. The most often, the risks are considered by standards and regulations and they determine general rules but they are not able to determine suitability for individual examples. The basic target of risk management is elimination or reduction of potential risk to permissible value. This target is achieved by application of risks evaluation process which consists of next steps: determination of device limit value, risks identification, and arrangement by importance, quantification, measures for reduction, application of reduction and final evaluation. Constituent steps of method for risks evaluation process are similar to Figure 1 (when the word "vibration" will be substituted by physical stress in device manipulation).[6]

Regulation 2006/42/ES about machine devices describes some types of risks which are related to machine devices. According to regulation, it is necessary to provide for protect before mechanical danger by elimination or reduction the loss of device stability, ensuring the ability to resist any straining in use, reducing risk of uncontrolled moves after the working with device, etc.[7]

III. Three alternatives examples of vibration plate rationalization modification

Rationalization arrangements for vibration reduction can be realized by multiple technical solutions. Example of redesign is vibration plates which have broad scale utilization in civil engineering. Vibration plates are used for compaction bedrocks and excavations, in maintenance of resinous road surface, in compaction of interlocking. Vibration plate guarantees transmission of vibration to machined surface by special self-cleaning lower plate. Vibration plate is manipulated by metallic handle with worker. Vibrations are transmitted by metallic handle from device to worker hands. Long-term vibration action to system hand – shoulder can cause the pathological changes in worker. They are mentioned activities which are categorized to hazardous work after the exceeding permissible exposition values of vibration acceleration level. In such a case company management has to pay extra money for workers. Target of rationalization modification is reduction of vibration transmission from vibration plate to worker hands.[9]

3.1 Principle of technical solution modification to vibration plate – 1st alternative[8].

The point of technical solution is characterized by achieving three other stages of vibro-isolation (vibrations absorption):

a) In lower part of the handle close to ten on connection (replacement of the rubber with the spring).

b) In upper part of the handle by creating suspended handle.

c) With spring connection of the new handle with original handle through a sleeve.

d) New rationalization modifications are evident on the Figure 2 and Figure 3 and presented by the items 1, 9 and 4 in the legend.

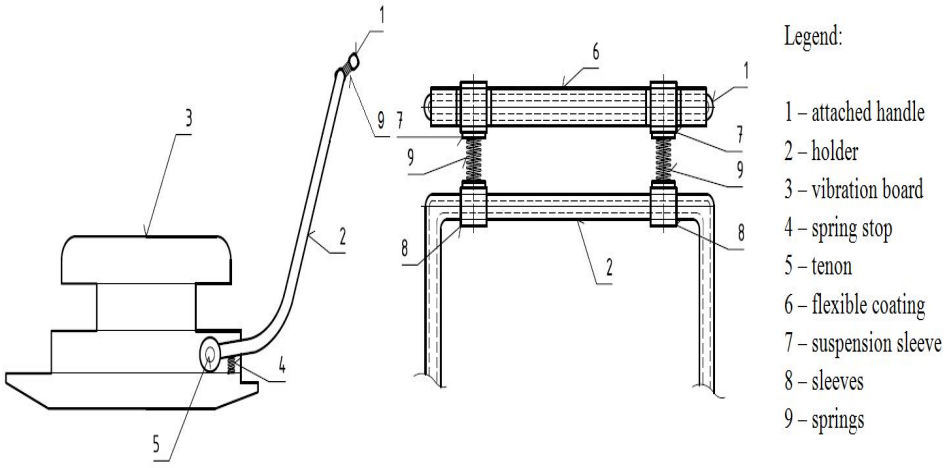

Fig. 2 Scheme of vibration board and the detail of a new handle

Fig. 3 View of vibration board before and after the modification

3.2 Principle of technical solution modification to vibration plate – 2nd alternative [8]

The second alternative is presented by solution which is characterized in that vibration plate is rotary connected by coupling joint with lower handle. Spring stop is situated between

vibration plate and lower handle. Division ring is fixed to free sides of lower handle and simultaneously they are pushed in two springs in lower handle. It is threaded sleeve from bellow and the sides of lower handle are inserted in cylinder of silencer and they are arranged against the extension of sleeve. Silencer cylinders have inserted spacer tubes and simultaneously silencer cylinders are connected by upper handle sides where the guards are threaded. Upper handle has horizontal part which is covered by elastic material. They are achieved three degrees of vibration isolation (vibration attenuation) which are presented in Figure 4:

a) In upper part of handle by means of flexible handgrip which is covered by elastic material.

b) Flexible connection of lower and upper part of handle by vibration silencers.

c) In lower part of handle by means of tenon joint with spring silencer.

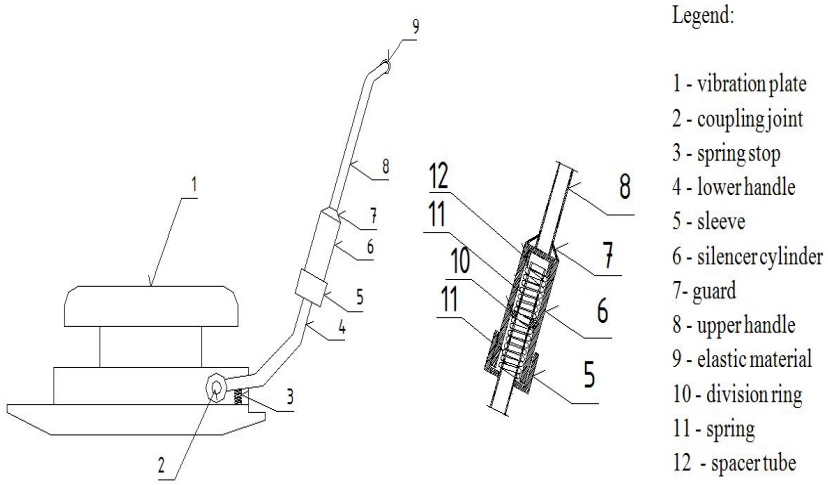

Fig. 4 Scheme of vibration board and the detail of a new handle with silencer

3.3 Principle of technical solution modification to vibration plate – 3rd alternative.[8]

Principle of the third alternative is characterized by pivot connection of vibration plate by ten on joint with lower handle. Spring stop is situated between vibration plate and lower handle. Division ring is fixed to free sides of lower handle it is secured by joint and simultaneously they are pushed in two springs in lower handle. It is threaded sleeve from bellow and the sides of lower handle are inserted in cylinder of silencer and they are arranged against the extension of sleeve. Silencer cylinders have inserted spacer tubes and simultaneously silencer cylinders are connected by upper handle sides where the guards are threaded. Upper handle has horizontal part (flexible handgrip) and it is covered by elastic material. Vibration plate with

spring-loaded handle and inertial dampening has fixed slide-in tubes with dampening inserts to silencer cylinders. Arms are impaled to slide-in tubes which are fixed by fastening bolts. Weights are impaled to arms and they are fixed by safety bolts.[14,15]

Purpose of bolts is dampening (lowering of amplitude) vibrations transmitted lengthwise handgrip towards to operators. They are achieved four degrees of vibration isolation (vibration attenuation) which are presented in technical documentation:

a) In upper part of handle by means of flexible handgrip which is covered by elastic material.

b) Flexible connection of lower and upper part of handle by vibration silencers.

c) Attachment of weight into upper part of silencers which cause the dampening of vibrations in upper part of handgrip.

d) In lower part of handle by means of tenon joint with spring silencer.[13]

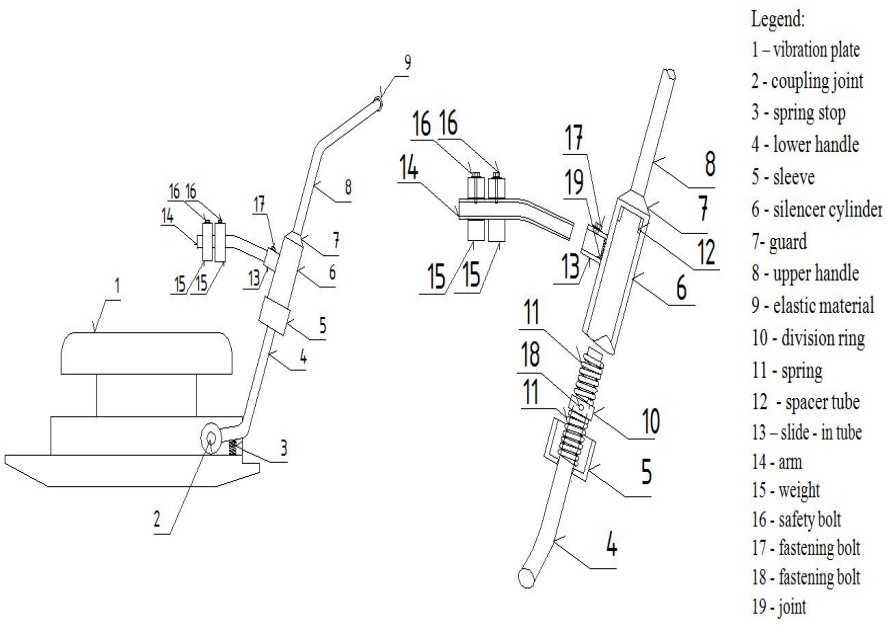

Fig. 5 Scheme of vibration board and the detail of a new handle with silencer and weight

IV. **Calculation of physical stress in handling with burden – vibration plate** . [10]

It is necessary to determination of relevant physical stress (e. g. for 60 minutes of activity) for different alternative because it is happened the increase of weight by redesign of vibration plate. Physical stress of worker with handling with burden is described as follow:

$$A = A_{CH} + A_P \tag{1}$$

A_{CH} – physical stress in walking given by:

$$A_{CH} = H_T * g * 0.03 * V_T * k_N * \frac{l_C}{l_K} * \frac{1}{\eta} \quad (2)$$

where

H_T – worker weight [kg],

g – gravitational acceleration [$m.s^{-2}$],

V_T – worker height [m],

k_N – coefficient of negative work [-],

l_C – total length of walk [m],

l_K – average length of step [m],

η – body efficiency in walk [-].

A_P – physical stress in transfer of carriage given by:

$$A_p = F * s_v * k_D * \frac{1}{\eta} \quad (3)$$

, where

F – force of pressure [N],

s_v – route of push [m],

k_D – coefficient of burden holding [-].

It was taken size values of average human into the consideration on calculation according to Fiala where the average weight is 71.4 kg and height has value 1.697 m .[10,11] Next table presented the percentage increase of physical stress for alternative above mentioned according to equations (1), (2) and (3).

Table 2 Comparison of physical stress in individual alternatives (60 minutes of activity)

Alternative	**Physical stress [kJ]**	**Increase of stress [%]**
Original solution	9307.879	-
1st alternative	9385.794	0.837
2nd alternative	9464.313	1.681
3rd alternative	9659.857	3.782

Table shows that worker has to generate size of the work 9307.879 kJ during 60 minutes on route 1 500 m at work with vibration plate. It was achieved 0.837% growth of worker physical stress in the first. It was added the silencer (weight 1.2 kg) in the second alternative and it was achieved 1.681% growth of physical stress. The third alternative acquired 3.782% growth in comparison with the first alternative after the addition of silencer (1.2 kg) and weight (1.5 kg).

V. Conclusion

Benefits of this technical solution being the last of many alternatives worked out during rationalization solution are the following:

A. Health – decreasing hand vibrations and disease prevention (HAVS: Hand – Arm Vibration Syndrome).

B. Organizational – the possibility of prolonging the work exposition with vibration board (work time) in reduced vibrations reached by described handle suspension.

C. Safety – antiskid treatment – good grip possibilities.

Presented example of rationalization measure within the machine by adding vibro-isolation gives the possibility of expositional work time expansion on vibration board from 60 minutes before modification to 297 minutes after modification measured on the gloved hand. This example is the output measurements – realized redesign from the first alternative.

Disadvantages include increase of vibration plate weight in the second alternative 1.2 kg growth and in the third alternative 2.7 kg growth. It is mildly increase of worker physical stress through this increase of weight.

Meaning of rationalization arrangements – solutions of devices redesign consists in participation of workers in their solutions in terms of manufacturing.

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