ISSN 1330-3651 (Print), ISSN 1848-6339 (Online)
UDC/UDK [621.926-7:676.021.36]:613.644

EFFECT OF THE DISC PROCESSING TECHNOLOGY ON THE VIBRATION LEVEL OF THE CHIPPER DURING OPERATIONS

Grzegorz M. Krolczyk, Jolanta B. Krolczyk, Stanislaw Legutko, Anica Hunjet

Subject review
The purpose of this article is to present the technological repair process of the mobile disc chipper used for crushing raw wood into chips of a certain size. Mobile disc chippers are used in the pulp - paper industry and fibreboard manufacturing plants. The paper presents the technology of repairing the disc chipper and the balancing process of the disc chipper in its own bearings. The article also presents the influence of unbalanced machine elements on the human body.

Keywords: *disc chippers, mechanical vibrations, safety engineering, wood*

Utjecaj tehnologije izrade na razinu vibracija stroja za usitnjavanje drva tijekom rada

Pregledni članak
Svrha ovog rada je prikazivanje tehnologije reparacije stroja za usitnjavanje drva koji se koristi za usitnjavanje drva u čestice određene veličine. Mobilni stroj za usitnjavanje drva koristi se u proizvodnji papira i postrojenjima za proizvodnju vlakana. Rad prikazuje tehnologiju popravka i balansiranje stroja. U članku se također predstavlja utjecaj djelovanja neuravnoteženih strojnih elemenata na ljudsko tijelo.

Ključne riječi: *drvo, mehaničke vibracije, stroj za usitnjavanje drva, zaštita na radu*

1 Introduction

Disc chippers are commonly used to crush raw wood into chips of a certain size. These machines work several hours a day. The employees operating the disc chippers are subjected to mechanical stimuli over a long period of time. Depending on the nature of the interactions (hits, shakes, jolts, vibrations), the rapid movements associated with them can cause various negative effects on the human body. The human body can easily be injured by the rapid movements. Even something like gravity acceleration can cause damage (e.g. damage to the blood circulatory system) in some individuals exposed for a longer time [1]. In addition to the side effects, the vibrations can cause a temporary disturbance in the perception of sight and hearing, and a loss of control of individual muscles. Changes in biological activities and the distractions caused by the vibrations can cause various kinds of problems in the interaction of man - machine or of man - environment. Disorders related to vibrations can lead to accidents and a loss of quality production. The biological effects of the impact of local and general vibrations on the human body are usually accompanied by functional side effects. These include, among others: slower physical reaction time, slower visual reaction time, coordination interference, excessive fatigue, insomnia, irritability, memory impairment. The mechanical vibrations from the vibration system on the human body may have a direct negative impact on individual tissues and blood vessels. The negative effects of occupational exposure to vibration in general are particularly reflected in the skeletal system and the internal organs of the human body. Mechanical vibrations can also cause excitation to the body, and even the cellular structures. Long-term human exposure to vibrations can cause a disturbance in the body leading ultimately to permanent, irreversible lesions. The nature of these changes depends on the type of vibration (general, local) a human is exposed to. Exposure to mechanical vibrations transmitted to the body through the upper limbs is mainly caused by lesions in the systems: circulatory (vascular), nervous, bone and synovial [1].

Mechanical vibrations of the disc chipper are caused by:

- the diameter and the amount of humidity of shredded wood bales,
- blunt knives,
- geometric parameters of the cutting system in the chipper,
- the size of the gaps in bales.

Not only mechanical vibrations, but also the noise may have a negative effect on human life and may be dangerous to workers' health. Noise can also exacerbate stress and increase the risk of accidents. Damages in hearing caused by noise are the most common occupational disease in Europe and present about one third of all work-related diseases [2]. The directive on noise [3] mentions the relationship between noise and accidents and also the requirement to take into account this relationship, especially in the assessment of the risks from noise. Noise can be a cause of accidents, because it prevents the employees' proper hearing and understanding speech and signals, hides the sound of approaching danger or warning signals (e.g. vehicles reversing signals), dissipates employees, such as drivers, intensifies stress related with a work which increases the likelihood of errors. Noise-induced hearing loss is usually the result of prolonged exposure to loud noise, such as mechanical work of a variety of mechanical devices, such as a temporal mixer with immovable chamber and vertical worm agitator [4].

Epidemiological studies conducted on large groups of workers have shown a close relationship between lesions detected in the vascular, nervous, and osteoarticular systems and the occurrence of local mechanical vibrations in the workplace. Thus, a combination of these changes, called vibration syndrome has been recognized as an occupational disease in many countries. Vibration syndrome is a major problem in all European countries, as well as the USA and Japan [5]. According to data collected by the Institute of Occupational Medicine in Lodz, vibration syndrome accounted for 3,4 % of all occupational diseases detected in Poland (above 5 % in 2002) and was on the list of diseases in 7th place after vocal organ diseases, occupational hearing loss, lung disease infections, invasive diseases of the skin, and chronic bronchitis [6].

Back pain syndrome, which is a consequence of the lesion, and occurs in people occupationally exposed to vibrations, was recognized in some countries (e.g. Belgium and Germany) as an occupational disease as well as a vibratory syndrome, which is a succession of local vibrations. Manual tools operators in the machining, steelworks, shipbuilding, converting, forestry, agriculture, stonework, mining and construction industries are particularly exposed to mechanical vibrations affecting humans through their upper limbs. Thus, the area of potential danger of this kind of vibration to employees is very extensive.

When it comes to mechanical vibrations and the general effect on the body, the individuals that are exposed are mainly drivers, machinists, and machine and road operators. In these cases the vibrations are transmitted to the body through the vehicle's seat to the pelvis, back, and sides.

Safety is a wide subject of interest which proper application allows obtaining safe product and working environment [7 ÷ 10].

2 Aim of the study

The purpose of this article is to present the technological repair process of the mobile disc chipper used for crushing raw wood into chips of a certain size. Disc chipper is the most widely used due to its ability to process a variety of wood feedstock and relative simplicity [11]. Mobile disc chippers are used in the pulp - paper industry and fibreboard manufacturing plants. The paper presents the technology of repairing the disc chipper and the balancing process of the disc chipper in its own bearings. The article also presents the influence of unbalanced machine elements on the human body.

3 Technological process

The work of the disc chippers is often characterized by a very uneven load that results from interruptions in the administration of wood and a diameter difference in the shredded shaft or their bundles [12, 13]. Because of the fact that the chipper operates at high speeds, its accurate balance is very important. The chipper wheel is embedded on a shaft mounted on a truck (Fig. 1), and the driver is also the operator of the chipper.

A multi-blade chipper with a flat blade (Fig. 2) consists of the same elements as a chipper with a profiled disc. A multi-blade chipper with a flat blade differs from a profiled disc chipper in its construction of the knife blades; ways of attaching the knives and their sharpening as well as the gutter solution and the bed knife [13].

The selection of the constructional features of the shaft, which is based only on strength, does not always work reliably. In many cases the proper functioning of the shaft is decided by the mechanical vibrations. Vibrations of the shaft may cause disturbances in the disc chipper, and is caused by vibrations in the whole machine along with the car. The phenomenon of resonant amplitude strengthening may cause the destruction of the entire machine.

Figure 1 Mobile disc chipper ready to be balanced

Figure 2 The assembled wheel of the disc chipper

The multi-blade disc chipper (Fig. 2) has mass about 3600 kg and an improper use of the disc may result in a dismounting of the disc from the machine, especially at the maximum speed. The frequency of vibration of the shaft chipper depends on the size and distribution of its mass (such as the knives or bed knives), the type of support of the shaft chipper, and its elastic properties. Periodically changing the lateral forces that occur, for example, an unbalanced rotating mass induces flexural vibrations. This type of vibration will increase the risk of the resonance amplitude. This is due to a reduction of the dimensions of the machine as well as an increase in the speed of the chippers. Vibrations in the chipper can be the result of external cyclic forces causing vibrations or other factors, such as the result of an improper seating wheel, where the centre of gravity does not coincide with the axis of the shaft. In order to prevent damage, high-speed shafts and the parts which are embedded on them, such as the chipper disc, must be statically and dynamically balanced;

and the rotational speed of the shaft should not differ significantly from the critical speed (at least 20 %). Balancing is the process of removing an imbalance. Practice shows that the rotor's speed, in which the nominal rotations are more than 1/5 of the standard critical rotations, must be dynamically balanced. Otherwise, the bearing vibration amplitude will exceed the threshold limit values [14]. Because of the size of the disc chipper and the absence of balancing machines with such a large span of bearings, it is balanced in its own bearings.

The balancing process begins by identifying the imbalance that is the main vector of the imbalance and the moment of the main imbalance. One of the basic parameters of dynamic balancing is the balancing speed, i.e. the speed at which the rotor imbalance is determined. Sample stages of the process of balancing the chipper are graphically presented in Fig. 3. The input data: the mass of the rotor: 3600 kg; mass radius: 840 mm; rotor speed: 574 rpm. The balance tolerance adopted Q: 4. The chipper was balanced on the car in its own bearings in accordance with the standard of tolerance ISO 1940-1:2003 [15] in balance class G 4.0 at a speed of 574 rpm.

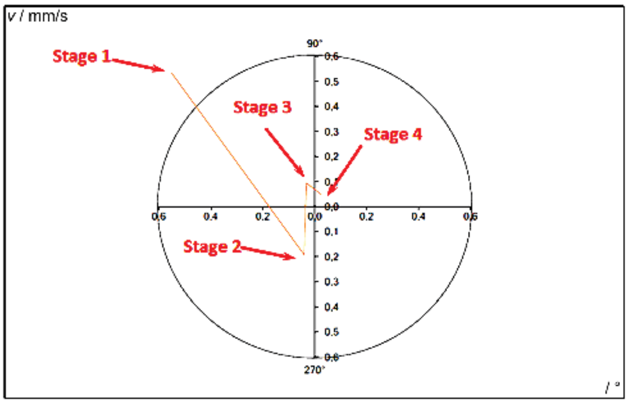

Figure 3 Graphical representation of the steps in the balancing process

As shown in Fig. 3, the balancing process consists of several steps (the red line represents the various stages of balancing). In the case described, a balance was reached in the fourth try (after three changes of the wheel mass). This state was achieved through the weld on a radius of 840 mm; weight of 1300,77 g. Because we add the balancing mass, not subtract it, we are talking about "positive mass correction." Before balancing the vibration amplitude at a frequency of rotation, it was 0,77 mm/s, and the remaining unbalanced Macc weight: 1298 g. Whereas, after balancing the amplitude rotational frequency, it was 0,05 mm/s, and the remaining unbalanced Macc weight: 94 g.

Before dynamic balancing the disc chipper, it should be performed in accordance with the technology. Disc was made of material S355J2G3. This type of steel was chosen because of its availability in such an unusual format needed to cut the blank on the plasma cutter. This material was chosen because of its tribological properties and the price of the material. The most important and most difficult operation was turning the rotary lathe. Difficulties occurred in the cutting blade, i.e. difficulty in the chip control, thermal and mechanical overload of the blade, strong impact of adhesion giving way to favourable conditions for the formation of a build-up edge, an increased appreciation of material deformation on the surface layer, and accelerated blade wear [16 ÷ 19]. An additional problem was the measurement of the disc because the disc in the turning process reached a temperature preventing a meaningful reading. In relation to problems in turning, boring holes and pockets for knives and bed knives caused problems only because of the large size (Fig. 4).

Figure 4 Boring holes in the disc chipper

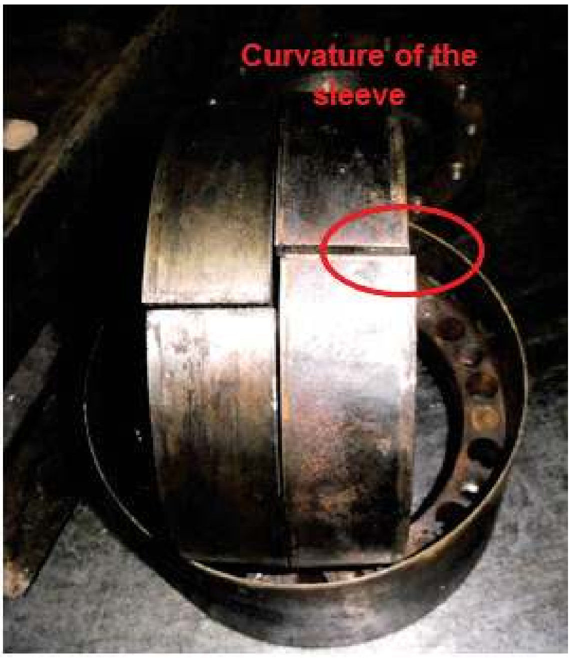

Figure 5 Visible curvature of the chipper taper bushings

Before balancing the wheel disc chipper and installing a new disc hub, it was levelled from the disc chipper and adhered to in order to compensate for the surface and transfused bearing shaft in place. Unbalanced centrifugal forces of inertia of the rotor caused vibrations of the weight disc chopper along with the rotor system supporting the bearing [20]. The taper bushings, along with the bearings, were changed because of visible damage (Fig. 5) due to the high speed of the rotating disc chopper.

4 Conclusions

The analysis shows that a number of steps must be fulfilled to ensure a long and reliable operation of the chipper disc. The greatest negative impact on a human have the vibrations caused by the high rotation of the disc, that is why dynamic balancing is so important in the process of repairing the parts of such a huge machine. Proper balancing must be supported by a well-completed technological process. Industrial practice shows that vibro-acoustic testing generally comes down to a guarantee of the measurements that are guaranteed by the manufacturer right after a complete overhaul of the machine. Once the machine is active, it works without almost any performing diagnostic tests, until the next repair job. This is due to a minimization of the cost of production of wood chips. Excessive vibration levels of the chipper will increase its wear and tear. Chipper wear results in breakdowns and disruptions in the production process. It may also cause occupational illnesses in the service staff and, in extreme cases, even lead to fatal accidents.

5 References

[1] Książek, M. Modelowanie i optymalizacja układu Człowiek – Wibroizolator – Maszyna. Wydawnictwo Politechniki Krakowskiej, Kraków, 1999.

[2] Dane opisujące czynnik łączący zagadnienia BHP i możliwości zatrudnienia, Europejska Agencja Bezpieczeństwa i Zdrowia w Pracy, 2002, ISBN 92-95007-66-2.

[3] Directive 2003/10/EC of the European Parliament and of the Council of 6 February 2003 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise).

[4] Królczyk, J.; Tukiendorf, M. Research on the impact mass fractions of Multi-element granular structure on the mixing process. // International Agrophysics. 22 (2008), pp. 45-52.

[5] Koradecka, D. Bezpieczeństwo pracy i ergonomia. T. 1-2. CIOP, Warszawa, 1999.

[6] Pepłońska, B.; Szeszenia-Dąbrowska, N. Occupational diseases in Poland. // Int. J. Occup. Med. Environ. Health. 4(2002), pp. 337-345.

[7] Gramza-Michalowska, A.; Korczak J. Vegetable products as HACCP system subject in modern gastronomy. // Acta Scientiarum Polonorum, Technologia Alimentaria. 7, 3(2008), pp. 47-53.

[8] Troniewski, L.; Witczak, S.; Filipczak, G.; Trembacz, J. Pool boiling of water-oil systems. Part II. Heat transfer. // Inzynieria Chemiczna i Procesowa. 24, 2(2003), pp. 207-216.

[9] Janiszewska, E.; Witrowa-Rajchert, D. The influence of powder morphology on the effect of rosemary aroma microencapsulation during spray drying. // International Journal of Food Science and Technology. 44, (2009), pp. 2438-2444.

[10] Sobczak, A.; Dobrzansk, Z.; Zygadlik, K. Hydroxyapatite from bone sludge by calcining in rotary kiln. // Przemysl Chemiczny. 89, 8(2010), pp. 1073-1076.

[11] Abdallah, R.; Auchet, S.; Méausoone, P. J. Experimental study about the effects of disc chipper settings on the distribution of wood chip size. // Biomass and Bioenergy. 35, 2(2011), pp. 843-852.

[12] Kawka, W.; Reczulski, M. Optymalizacja pracy rębaków helikoidalnych w celu zmniejszenia zużycia energii do ich napędu i poprawy jakości zrębków. // Przegląd Papierniczy. 67, (2001), pp. 412-416.

[13] Reczulski, M. Effect of disc chipper design parameters and physical properties of wood on chips thickness. // Przegląd Papierniczy. 69, 7(2013), pp. 344-350.

[14] Gryboś, R. Drgania maszyn. Wydawnictwo Politechniki Śląskiej, Gliwice, 2009.

[15] ISO 1940-1:2003. Mechanical vibration - Balance quality requirements for rotors in a constant (rigid) state - Part 1: Specification and verification of balance tolerances.

[16] Krolczyk, G.; Nieslony, P.; Legutko, S. Microhardness and Surface Integrity in Turning Process of Duplex Stainless Steel (DSS) for Different Cutting Conditions. // Journal of Materials Engineering and Performance, 23, 3(2014), pp. 859-866.

[17] Krolczyk, G.; Legutko, S.; Gajek, M. Predicting the surface roughness in the dry machining of duplex stainless steel. // Metalurgija. 52, 2 (2013), pp. 259-262.

[18] Krolczyk, G.; Legutko, S.; Raos, P. Cutting wedge wear examination during turning of duplex stainless steel. // Tehnički Vjesnik-Technical Gazette. 20, 3(2013), pp. 413-418.

[19] Krolczyk, G.; Legutko, S.; Gajek, M. Effect of the cutting parameters impact onto tool life in duplex stainless steel turning process. // Tehnički Vjesnik-Technical Gazette. 20, 4(2013), pp. 587-592.

[20] Kaczmarek, J.; Niecewicz, G. Zwalczanie drgań i hałasu. Wydawnictwo Wyższej Szkoły Morskiej w Szczecinie, Szczecin, 2002.

Authors' addresses

Grzegorz M. Krolczyk PhD. Eng.
Faculty of Production Engineering and Logistics
Opole University of Technology
76 Prószkowska Street, 45-758 Opole, Poland
E-mails: g.krolczyk@po.opole.pl

Jolanta B. Krolczyk PhD. Eng.
Department of Biosystems Engineering
Opole University of Technology
5 Mikolajczyka Street, 45-271 Opole, Poland
E-mails: j.krolczyk@po.opole.pl

Stanislaw Legutko Prof. DSc. PhD. Eng., Prof. h. c.
Faculty of Mechanical Engineering and Management
Poznan University of Technology
3 Piotrowo Street, 60-965 Poznan, Poland
E-mail: stanislaw.legutko@put.poznan.pl

Anica Hunjet, dr. sc.
Ministry of Science, Education and Sport
Donje Svetice 38, 10000 Zagreb, Croatia
E-mail: anica.hunjet@mzos.hr