CONFERENCE "ERGONOMICS AND OCCUPATIONAL HEALTH", Zagreb, 11th and 12th November, 1994
Arh hig rada toksikol 1995;46:33-44

COMMUNICATION
UDC 613.644:621.924

HAND TRANSMITTED VIBRATIONS CAUSED BY ORBITAL HAND SANDING MACHINES

VLADO GOGLIA, STJEPAN RISOVIĆ AND RUŽICA BELJO

Faculty of Forestry, University of Zagreb, Zagreb, Croatia

The paper reports and analyses results of vibration measurement carried out on orbital hand sanding machines. Vibrations were measured on the front and rear handles of the FESTO LRB-W1 and LRB-T1 orbital hand sanding machines and at two points on the holding handle of the FESTO RTL-F1 hand sanding machine. The measured levels of the weighted vibration accelerations were compared to the daily exposure limits according to ISO 5349, ISO/TC 108/SC4/14 and NF E90-402. Daily exposures for each type of sanding machine were determined according to the same standards.

Key terms:
daily exposure limits, health risk, permanent health damage, vibration acceleration analysis

Sanding machines of various forms, sizes and ways of coupling the hand-arm system to the machine are sometimes used in wood machining and in machining of welding joints and other metal surfaces. Many workers use such sanding machines over a full working day, others do so only occasionally. Intensive vibration can be transmitted to the hands and arms of the operators causing various patterns of diseases. To protect workers against serious health impairment caused by vibrations, the levels of hand-transmitted vibrations were measured at the joinery in Lokve and at the Integrated Woodworking Plant in Delnice (DIP-Delnice) in Croatia. The paper reports on the results of these measuerements and their analysis.

METHOD AND EQUIPMENT

Vibrations were measured on three types of FESTO orbital hand sanding machines commonly used in woodworking: LRB-W1, LRB-T1 and RTL-F1.

Basic technical characteristics of the LRB-W1 type:
- compressed-air motor,
- motor rotation frequency 7000 min^{-1} at an air pressure of 5-6 bar,
- displacement 4 mm,
- number of operation cycles 14000 min^{-1},
- air consumption 0.36 m^3/min,
- sanding area 115 x 225 mm^2
- weight 2.7 kg

Basic technical characteristics of the LRB-T1 type:
- compressed-air motor,
- motor rotation frequency 7000 min^{-1} at an air pressure of 5-6 bar,
- displacement 4 mm,
- number of operation cycles 14000 min^{-1},
- air consumption 0.36 m^3/min,
- sanding area 115 x 225 mm^2
- weight 2.6 kg

Basic technical characteristics of the RTL-F1 type:
- compressed-air motor,
- motor rotation frequency 5600 min^{-1} at an air pressure of 5 bar,
- displacement 5 mm,
- number of operation cycles 11200 min^{-1},
- air consumption 0.25 m^3/min,
- sanding area 95 x 175 mm^2
- weight 1.8 kg

The 120 grain size abrasive paper was used on the sanding machines during testing.

Testing plan and testing conditions

The vibration measurements on the orbital hand sanding machine handles were carried out accroding to the International Standard ISO 5349 in normal working conditions. On the FESTO LRB-W1 orbital hand sanding machine measurements were made on both, the front and the rear handle, at idling and at sanding. On the FESTO LRB-T1 type measurements were also made on both, the front and the rear handle, but only at sanding, and finally, on the FESTO RTL-F1 type measurements were made at two points on the handle, as this machine type is only single-handled. All three types of machine are shown in Figure 1.

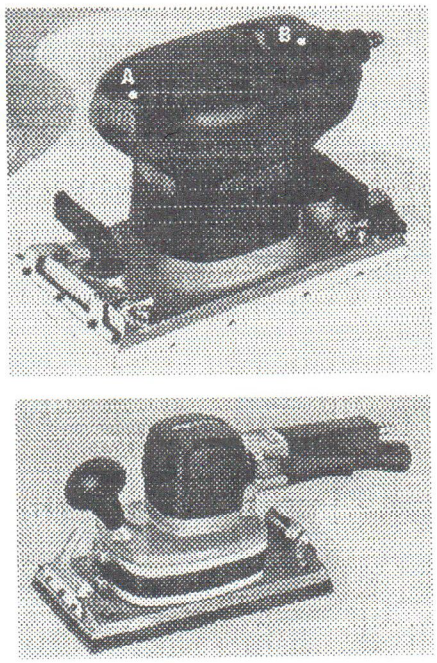

Figure 1 *FESTO LRB-W1, FESTO RTL-F1 and LRB-T1 orbital hand sanding machines*

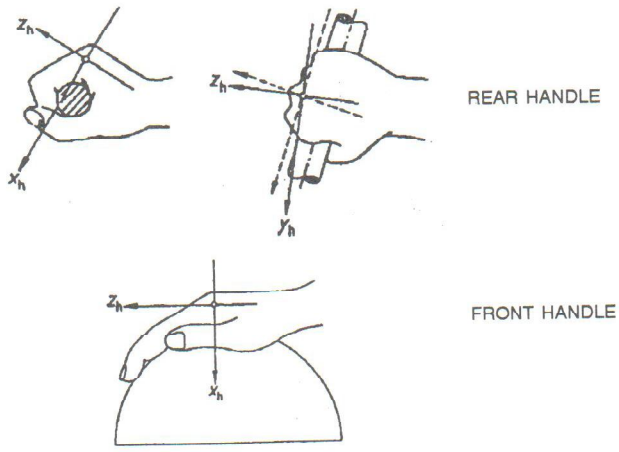

Figure 2 *Coordinate system for the hand at measuring vibrations on rear and front handles*

In accordance with the recommendations of the ISO 5349 the vibrations were measured simultaneously in all three axes of the coordinate system and tape-recorded. The directions of the axes are shown in Figure 2.

The tape-recorded measurement results were analysed in the Department for Mechanical Engineering of the Faculty of Forestry, University of Zagreb. The following equipment was used for the vibration measurements and for data analysis: accelerometers type 04374 Brüel & Kjaer, accelerometer mount 3-axial Faculty of Forestry, Zagreb, amplifiers type 2635 Brüel & Kjaer, tape recorders type 7003 Brüel & Kjaer, frequency analyser type 2132 Brüel & Kjaer, computer HP 9835A Hewlett & Packard.

RESULTS

Measurements were carried out simultaneously in all three axes of the coordinate system. The frequency weighted acceleration levels for all three axes of the front and rear handles of the FESTO-LRB-W1 orbital hand sanding machine at idling are given in Table 1. Table 1 also shows the weighted acceleration sum (WAS values). The acceleration measured in each of the three axes was analysed in one-third octave bands (Figure 3).

Table 1. *Weighted acceleration level and weighted acceleration sum (WAS) for the FESTO LRB-W1 orbital hand sanding machine measured on handles at idling, m/s²*

Handle	Direction	Measurement no.						Mean value	WAS
		1	2	3	4	5	6		
Front	x	5.39	5.08	5.11	5.01	5.19	4.80	5.10	
	y	2.36	2.24	2.22	2.29	2.90	2.34	2.39	7.38
	z	5.02	4.58	4.57	4.56	4.54	5.36	4.77	
Rear	x	2.09	1.75	1.73	1.44	1.34	1.74	1.68	
	y	3.01	2.35	2.36	2.37	2.26	2.01	2.39	3.17
	z	1.38	1.11	1.23	1.23	1.22	1.23	1.23	

If the maximum values of the weighted accelerations in the individual axes on the front and rear handles measured at idling are substituted into the dose-effect diagram in accordance with the ISO 5349 as shown in Figure 4, it can be presumed that the measured vibration acceleration level on the front handle will cause permanent damage in 10% of the operators after just over five years of exposure time.

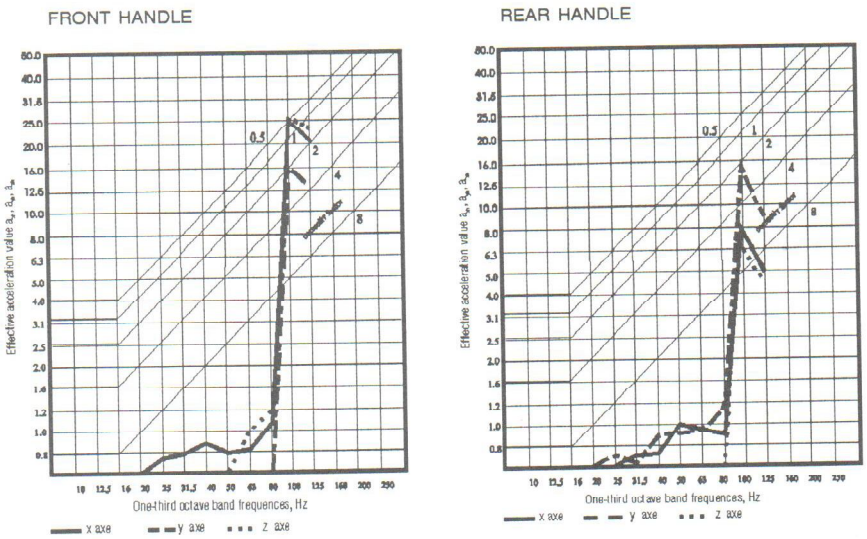

Figure 3 *Acceleration analysed in one-third octave bands on the front and on the rear handles of the LRB-W1 orbital hand sanding machine at idling*

If the measured vibration levels are substituted into the daily exposure limits diagram in accordance with the NF E90-402 Standard as shown in Figure 5, the daily exposure time to the safety limit amounts to just over four hours.

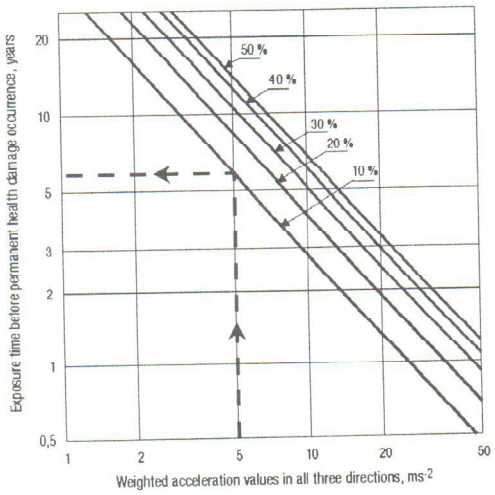

Figure 4 *Probability of permanent health-damage to the operator of the LRB-W1 at idling*

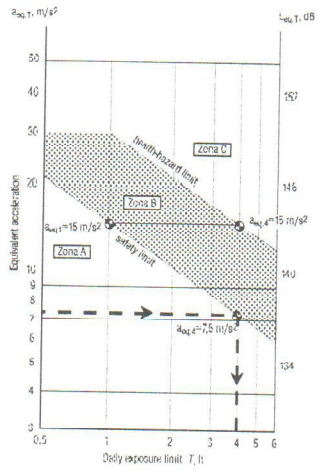

Figure 5 *Daily exposure limit diagram for the operator of the LRB-W1 at idling*

The frequency weighted acceleration level for all the three axes of the front and rear handles of the LRB-W1 type at sanding are shown in Table 2. The accelerations measured in the three axes were analysed in one-third octave bands (Figure 6).

Table 2 *Weighted acceleration level and weighted acceleration sum (WAS) for the FESTO LRB-W1 orbital hand sanding machine measured on handles at sanding, m/s²*

Handle	Direction	Measurement no.						Mean value	WAS
		1	2	3	4	5	6		
Front	x	3.51	5.36	5.51	5.81	5.58	5.81	5.26	13.82
	y	3.16	3.75	3.36	3.8	2.90	2.80	3.29	
	z	11.6	11.5	11.6	12.3	14.8	11.2	12.16	
Rear	x	15.9	15.6	14.9	14.8	15.0	14.8	15.17	20.70
	y	14.9	13.4	14.4	13.4	13.2	13.4	13.68	
	z	3.24	3.36	2.7	3.06	2.55	2.78	2.95	

If the maximum values of the weighted accelerations in the individual axes on the front and rear handles measured at sanding are substituted into the dose-effect diagram (Figure 7), it is obvious that the measured vibration acceleration level will cause finger blanching in 10% of the operators in less than two years of exposure time. Figure 8 shows that the level of the measured weighted ac-

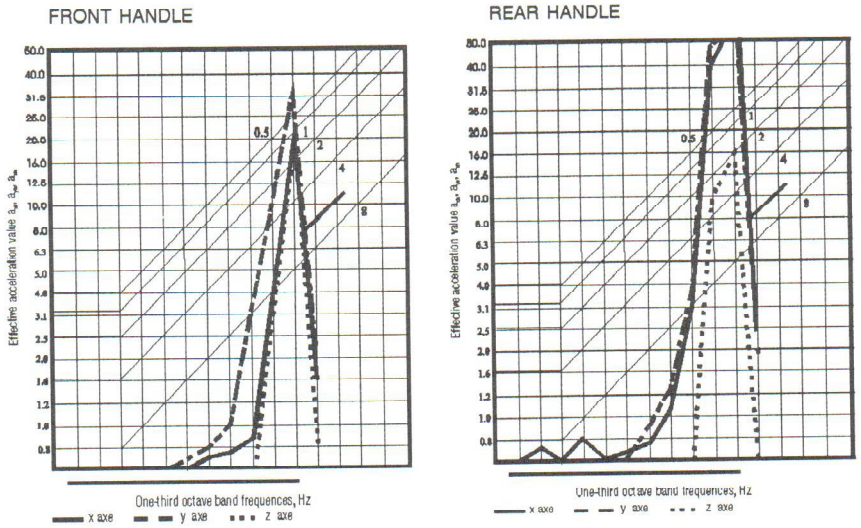

Figure 6. *Acceleration analysed in one-third octave bands on the front and on the rear handles of the LRB-W1 orbital hand sanding machine at sanding*

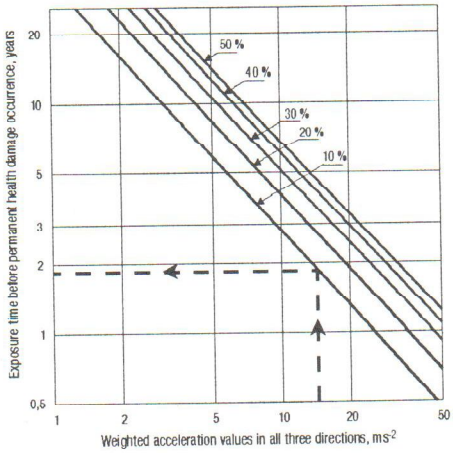

Figure 7. *Probability of permanent health-damage to the operator of the LRB-W1 at sanding*

celerations allows the maximum daily exposure of only 0.5 hours, if the operator's daily exposure is to be kept under the safety limit.

The results of measurement for the orbital hand sanding machine LRB - T1 are given in Table 3. Due to an interruption that occurred in the direction of the y-axis during vibration measurements on the rear handle it was impossible to

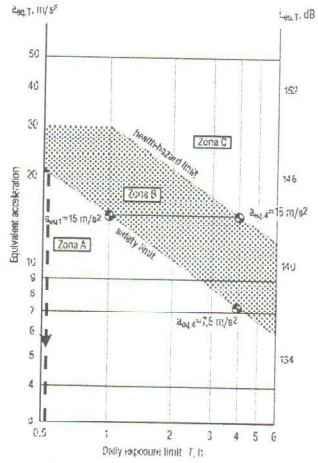

Figure 8. *Daily exposure limit diagram for the operator of the LRB-W1 at sanding*

make complete analysis of the measurement results. But, as the LRB-T1 and LRB-W1 types are almost identical, it can just be stated that the WAS value recorded on the front handle of the LRB-T1 was negligibly lower than the one recorded for the LRB-W1. However, the differences in the weighted accelerations measured in the three axes are much more significant.

Table 3. *Weighted acceleration levels and weighted acceleration sum (WAS) for the FESTO RTL-F1 orbital hand sanding machine measured on handles at sanding, m/s²*

Handle	Direction	Measurement no.						Mean value	WAS
		1	2	3	4	5	6		
Front	x	3.28	3.20	2.96	4.85	3.60	4.35	3.71	11.4
	y	6.12	5.97	6.49	6.50	6.42	6.42	6.32	
	z	6.86	6.06	9.25	9.52	11.2	9.4	8.73	
Rear	x	5.25	5.76	5.62	5.73	5.20	–	5.51	–
	y	–	–	–	–		–	–	
	z	8.13	7.40	6.88	6.92	8.43	6.57	7.39	

The FESTO RTL-F1 orbital hand sanding machine is a single-handed sanding machine and its handle can be gripped in different ways. The measurements were therefore made at two points ("A" and "B") at the front and rear end of the handle, as shown in Figure 1. They were made only at sanding as it had been established earlier that much higher vibrations occurred at sanding than at idling.

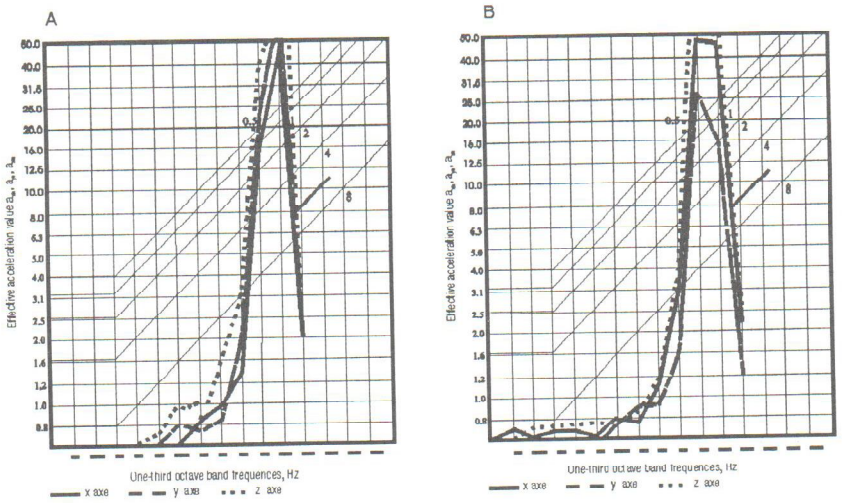

Figure 9 *Acceleration analysed in one-third octave bands at the "A" (left) and "B" (right) points on the handle of the RTL-F1 at sanding*

Measurements were carried out simultaneously in all three axes of the coordinate system. Six samples were taken and mean values and WAS values were calculated. Results are given in Table 4.

Table 4 *Weighted acceleration level and weighted acceleration sum (WAS) for the FESTO RTL-F1 orbital hand sanding machine measured at the "A" and "B" point on the handle at sanding, m/s²*

Handle	Direction	Measurement no. 1	2	3	4	5	6	Mean value	WAS
Point "A"	x	7.47	6.95	6.86	7.82	6.94	7.08	7.19	15.79
Front	y	10.4	9.39	9.49	8.72	8.72	7.73	8.90	
End	z	14.9	8.44	11.1	10.6	9.76	10.5	10.88	
Point "B"	x	12.7	11.9	10.6	11.7	12.3	10.2	11.57	20.09
Rear	y	5.49	2.38	2.5	2.45	2.19	2.19	2.87	
End	z	18.6	13.6	17	18.5	13.4	15.9	16.17	

The accelerations measured in each of the three axes and at the two measuring points were analysed in one-third octave bands and are shown in Figure 9.

The maximum value of the weighted accelerations in the individual axes was substituted into the dose-effect digram as shown in Figure 10. It can be presumed

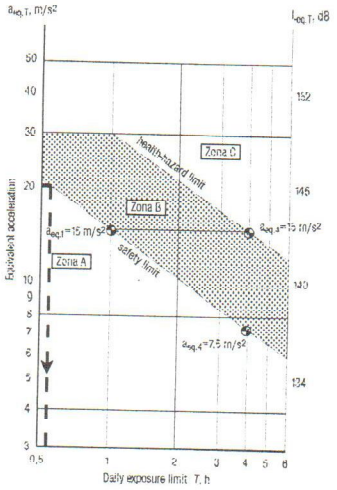

Figure 10 *Probability of permanent health damage to the operator of the LRB-F1 at sanding*

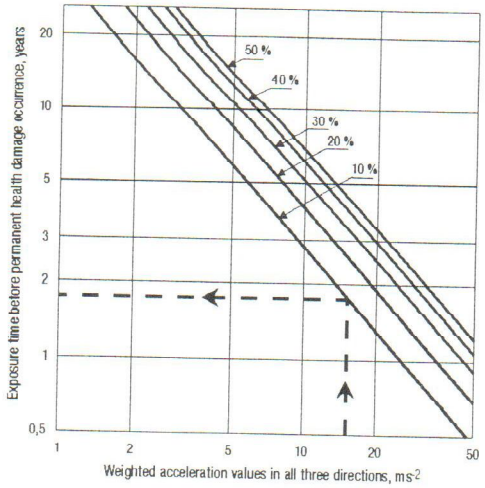

Figure 11 *Daily exposure limit diagram for the operator of the LRB-F1 at sanding*

from the diagram that the vibration acceleration level measured at sanding will cause permanent health damage in 10% of the operators in less than two years of exposure time. Figure 11 shows the daily exposure limit of only 0.5 hours.

CONCLUSIONS

The measurement results and vibration acceleration analysis confirm that the risk of permanent health damage to persons operating orbital hand sanding machines is quite real. As a matter of fact, this investigation work was initiated because of health damages observed with sanding machines operators in the woodworking and woodprocessing plants in Croatia. Daily exposure should therefore be strictly limited in accordance with the recommended exposure times. The efficiency of the production process should be maintained by means of work organization and work schedules should be arranged to include vibration-free periods.

REFERENCES

1. *Henich D.* Razvoj metoda mjerenja i utvrđivanja dozvoljenih granica izlaganja buci i vibracijama prenesenih putem ruke-šake. U: Zbornik savjetovanja "Mehanizacija šumarstva u teoriji i praksi", Opatija 1983.
2. *Golja V, Lipoglavšek M, Horvat D, Risović S, Sever S.* Prilog istraživanju buke i vibracija motornih pila lančanica. Savjetovanje "Životni i radni uvjeti proizvodnih radnika u šumarstvu i njihov utjecaj na zdravstveno stanje i socioekonomski položaj", Rovinj, 1990.
3. *Šestan A.* Vibracije i njihove uzbude u ručnih brusilica. Strojarstvo 1984;26:297-302.
4. ISO 53492: Guidelines for the measurement and the assessment of human exposure to hand transmitted vibration.
5. ISO/TC 108/SC4/14: Guide for the evalution of the human exposure to hand transmitted vibration.
6. NF-E90-402- Guide pour l'evaluation de l'exposition des individus aux vibrations transmises aux members supérieurs.
7. ISO 5348: Mechanical vibration and shock - Mechanical mounting of accelerometers.
8. IEC 651: Sound level meters.
9. ISO 5347: Methods of calibration of vibration and chock pickups.

Sažetak

VIBRACIJE PRENESENE NA RUKE RUKOVATELJA ORBITALNIM RUČNIM BRUSILICAMA

Pneumatskim orbitalnim brusilicama, koje se upotrebljavaju u završnoj obradi drva i pri obradi zavarenih spojeva te drugih metalnih površina, na ruke rukovatelja prenose se vibracije. S obzirom na opasnost da se pri rukovanju takvim brusilicama pojave teža oštećenja rukovateljeva organizma istraživane su razine vibracija kojima su rukovatelji izloženi. Mjerenja su obavljena na tri tipa brusilica koje se najčešće rabe za završnu obradu drva: FESTO LRB-W1, FESTO LRB-T1 i FESTO RTL-F1. Mjerenje vibracija na ručkama orbitalnih brusilica obavljeno je u skladu s normom ISO 5349 u normalnim radnim uvjetima. Analiza rezultata mjerenja provedena je u laboratoriju. Mjerenja su obavljena istodobno u sve tri koordinatne osi. Smjer osi, i u skladu s njim položaj akcelerometra, izabran je prema uputama u ISO 5349. Za sve tri osi izračunana je vrednovana vrijednost ubrzanja vibracije. Na osnovi tih vrijednosti izračunan je

rezultantni vektor vrednovanih ubrzanja (WAS). Za svaku os napravljena je i tercna analiza, a rezultati su grafički prikazani. Mjerenja su pokazala da će 10% rukovatelja brusilicom LRB-W1 zadobiti trajna oštećenja već nakon pet godina rada. Rukovatelji brusilicom tipa RTL-F1 imat će iste probleme za manje od dvije godine rada. Iz rezultata mjerenja se vidi da izmjerena razina vrednovanih ubrzanja vibracija dopušta maksimalno dnevno izlaganje od samo 0,5 sati. Stoga treba organizacijom posla (češćim zamjenama rukovatelja) omogućiti zaštitu rukovatelja i osigurati potrebnu učinkovitost čitavoga proizvodnog sustava.

Ključne riječi:
maksimalna dnevna izloženost, rizik za zdravlje, trajno oštećenje, vrednovanje ubrzanja vibracija

Request for reprints:

Professor Vlado Goglia
Faculty of Forestry
University of Zagreb
Svetošimunska 25
10000 Zagreb, Croatia