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Application of low-cost accelerometers for measurement of whole body vibrations

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Whole body vibrations (WBV) and health risks

- What’re whole body vibrations
  - Usually occur while operating vehicles
  - Leads to lower back pain and neck pain
  - 10% of the male working population of Sweden is subjected to whole body vibrations at least ¼ of the working time
  - Among blue-collar workers this could be as high as 25%

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What does the Swedish work environment law demand?

- **AFS 2001:1, 8 §**

The employer must regularly examine the working conditions and assess the risks ...

- **AFS 2005:15, 4-7 § §**

…that may arise as a result of exposure to vibrations at work.

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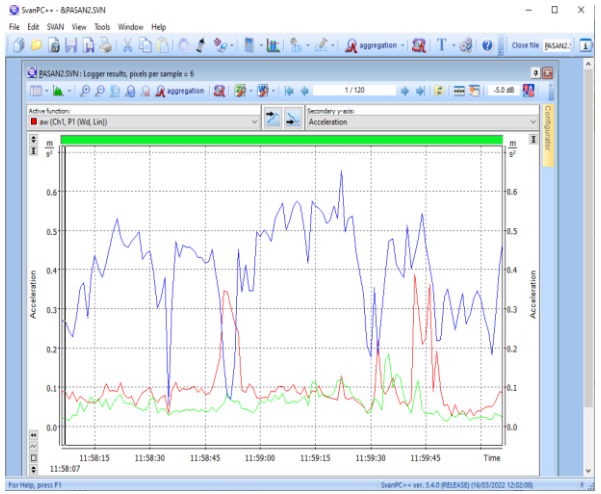
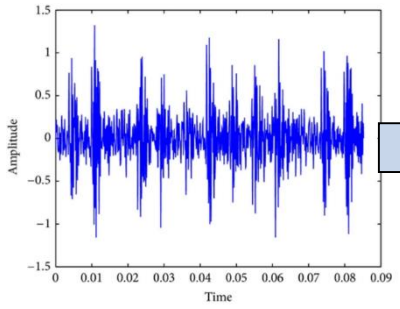
Typical whole body vibration risk assessment

- Find daily vibration dose levels
- Check whether they exceed “Action” or “Limit” values
- Take remedial actions (immediate if necessary)

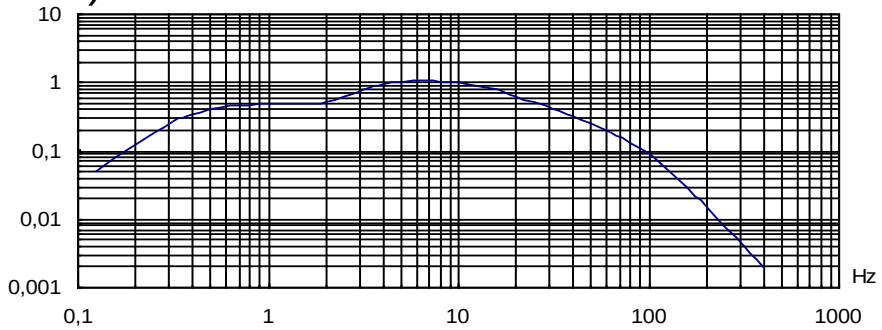


WBV exposure calculation – Step 1

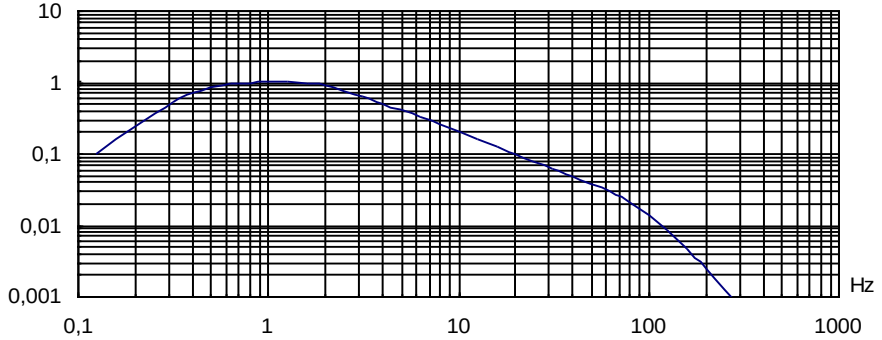
Frequency weighted filtering according to iso2631 WBV-filter specifications

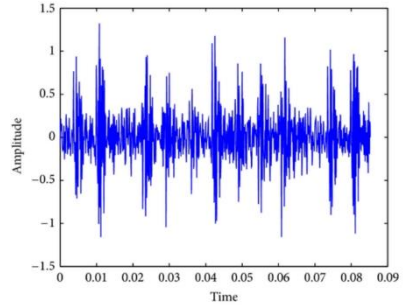


Wk (Z vertical)



Wd (X/Y, horizontal)





WBV exposure calculation – Step 2

$$a_w = \sqrt{\frac{1}{T}\int_0^T a_w^2(t)\,dt}$$

$$A(8) = a_w \sqrt{\frac{T}{T_0}}$$

$$A(8) = \sqrt{A_1(8)^2 + A_2(8)^2 + \ldots}$$

Vibrationsvärde, a_{hv}, m/s²

40	267	800	1600	3200	6400	9600	12800	16000	19200	25600	32000
30	150	450	900	1800	3600	5400	7200	9000	10800	14400	18000
25	104	313	625	1250	2500	3750	5000	6250	7500	10000	12500
20	67	200	400	800	1600	2400	3200	4000	4800	6400	8000
19	60	181	361	722	1444	2166	2888	3610	4332	5776	7220
18	54	162	324	648	1296	1944	2592	3240	3888	5184	6480
17	48	145	289	578	1156	1734	2312	2890	3468	4624	5780
16	43	128	256	512	1024	1536	2048	2560	3072	4096	5120
15	38	113	225	450	900	1350	1800	2250	2700	3600	4500
14	33	98	196	392	784	1176	1568	1960	2352	3136	3920
13	28	85	169	338	676	1014	1352	1690	2028	2704	3380
12	24	72	144	288	576	864	1152	1440	1728	2304	2880
11	20	61	121	242	484	726	968	1210	1452	1936	2420
10	17	50	100	200	400	600	800	1000	1200	1600	2000
9	14	41	81	162	324	486	648	810	972	1296	1620
8	11	32	64	128	256	384	512	640	768	1024	1280
7	8	25	49	98	196	294	392	490	588	784	980
6	6	18	36	72	144	216	288	360	432	576	720
5,5	5	15	30	61	121	182	242	303	363	484	605
5	4	13	25	50	100	150	200	250	300	400	500
4,5	3	10	20	41	81	122	162	203	243	324	405
4	3	8	16	32	64	96	128	160	192	256	320
3,5	2	6	12	25	49	74	98	123	147	196	245
3	2	5	9	18	36	54	72	90	108	144	180
2,5	1	3	6	13	25	38	50	63	75	100	125
2	1	2	4	8	16	24	32	40	48	64	80
	5 min	15 min	30 min	1h	2h	3h	4h	5h	6h	8h	10h

Exponeringstid, T →

$$VDV = \left\{\int_0^T [a_w(t)]^4\,dt\right\}^{\frac{1}{4}}$$

$$VDV_{total} = \left(\sum_i VDV_i^4\right)^{\frac{1}{4}}$$

Daily WBV Exposure

Daily exposure points

Optional VDV exposure

"Action" = 0.5ms^{-2} (100points) ; "Limit" = 1.1ms^{-2} (484 points)

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Why not enough WBV measurements?

Is it cost and complexity of equipment?

Can we use cheap wearable accelerometers?

Axivity AX3

- Cheap (129 €)
- No cables – self contained
- Small, robust and handy (23 X 32.5 X 7.6 m with IPx8 and IP6x)

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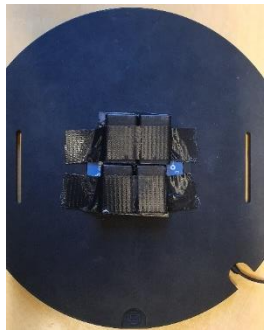
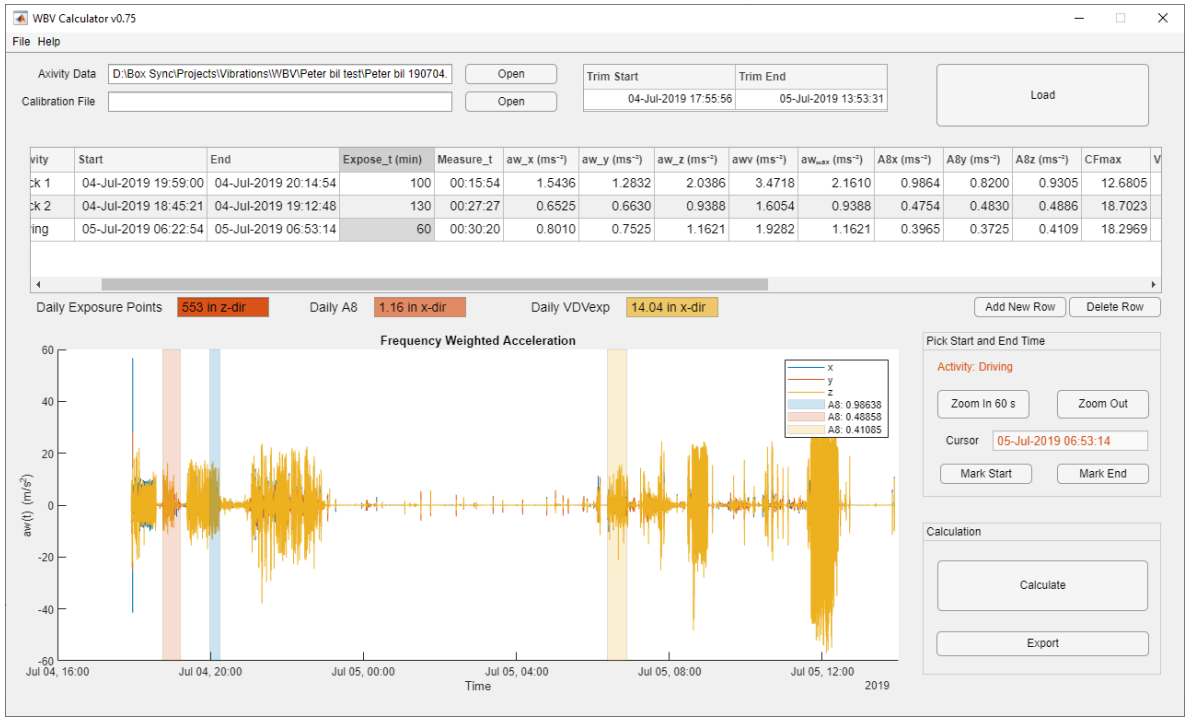
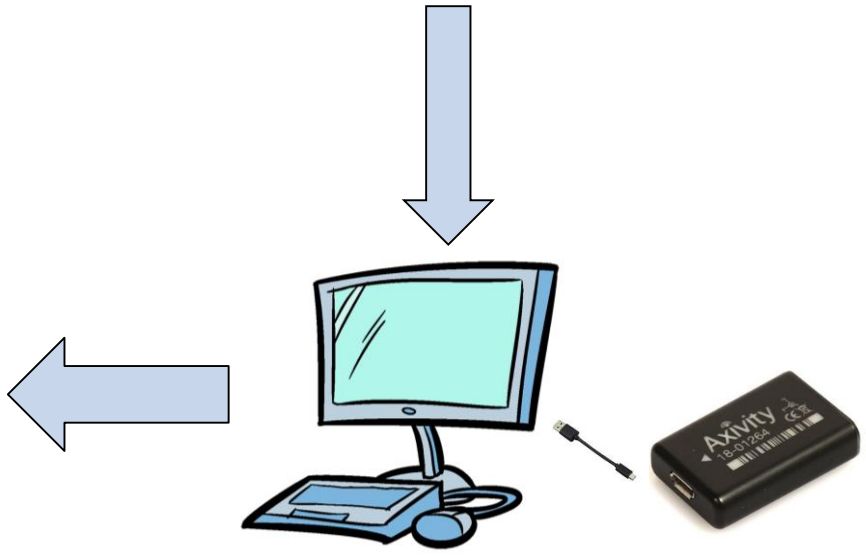
Introducing Axivity AX3 based WBV Calculator – A tool to measure whole body vibration exposure







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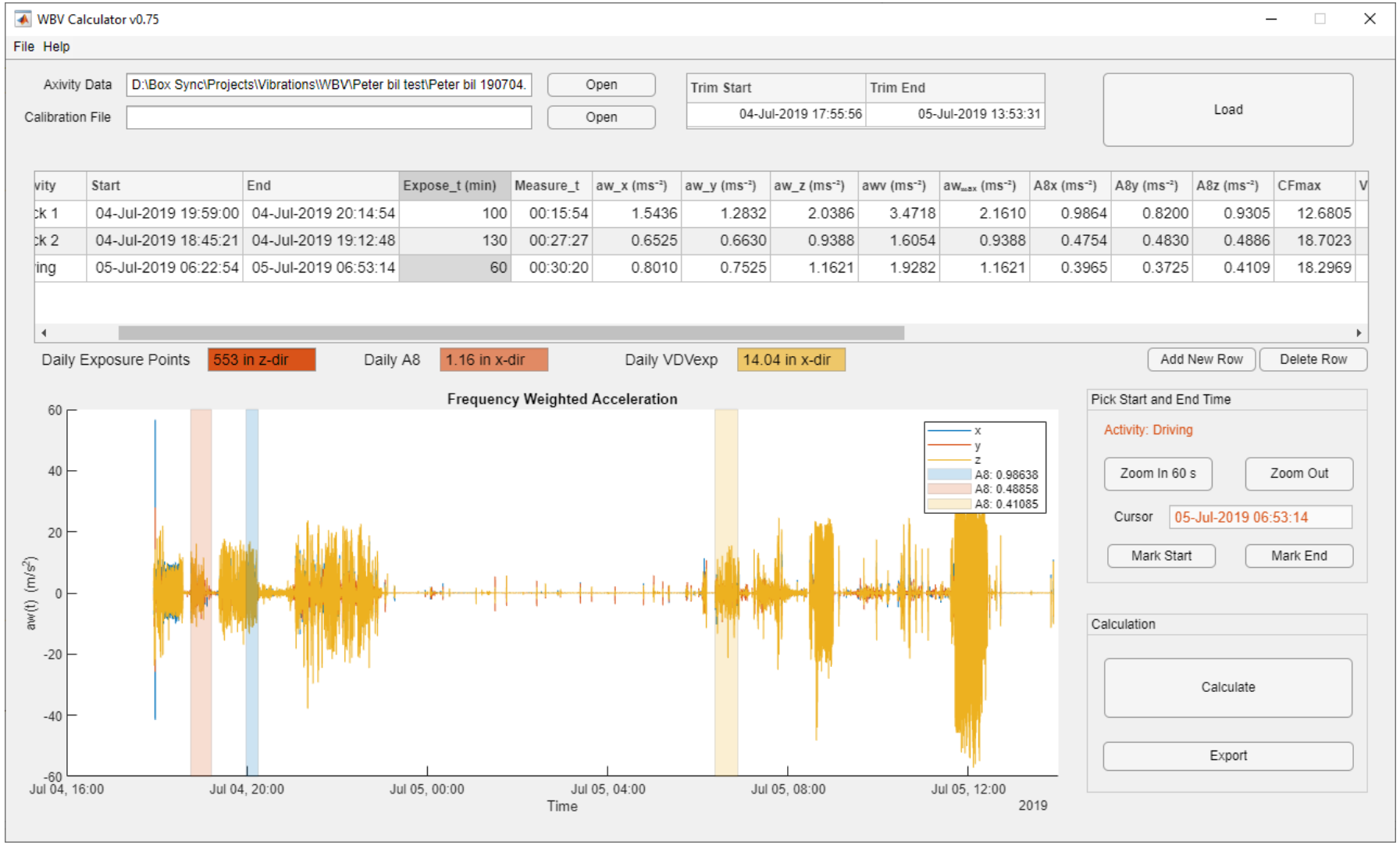
User friendly GUI



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User Interface – Output: Exposure details

Device ID	Activity	Start	End	Expose_t (min)	Measure_t	aw_x (ms^{-2})	aw_y (ms^{-2})	aw_z (ms^{-2})	awv (ms^{-2})	aw_{max} (ms^{-2})	A8x (
29276	Truck 1	04-Jul-2019 19:59:00	04-Jul-2019 20:14:54	100	00:15:54	1.5436	1.2832	2.0386	3.4718	2.1610	0
29276	Truck 2	04-Jul-2019 18:45:21	04-Jul-2019 19:12:48	130	00:27:27	0.6525	0.6630	0.9388	1.6054	0.9388	0
29276	Driving	05-Jul-2019 06:22:54	05-Jul-2019 06:53:14	60	00:30:20	0.8010	0.7525	1.1621	1.9282	1.1621	0

)	aw_{max} (ms^{-2})	A8x (ms^{-2})	A8y (ms^{-2})	A8z (ms^{-2})	CFmax	VDVmax ($ms^{-1.75}$)	VDVx ($ms^{-1.75}$)	VDVy ($ms^{-1.75}$)	VDVz ($ms^{-1.75}$)	Points_x	Points_y	Points_z
718	2.1610	0.9864	0.8200	0.9305	12.6805	23.8158	16.6263	12.7353	23.8158	400	400	400
054	0.9388	0.4754	0.4830	0.4886	18.7023	16.7601	11.4636	9.0342	16.7601	81	81	81
282	1.1621	0.3965	0.3725	0.4109	18.2969	18.7285	12.2421	9.3034	18.7285	61	61	72

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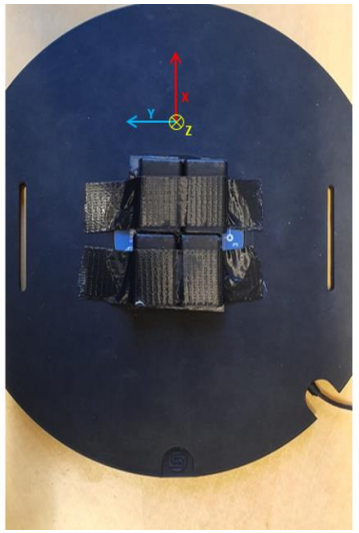
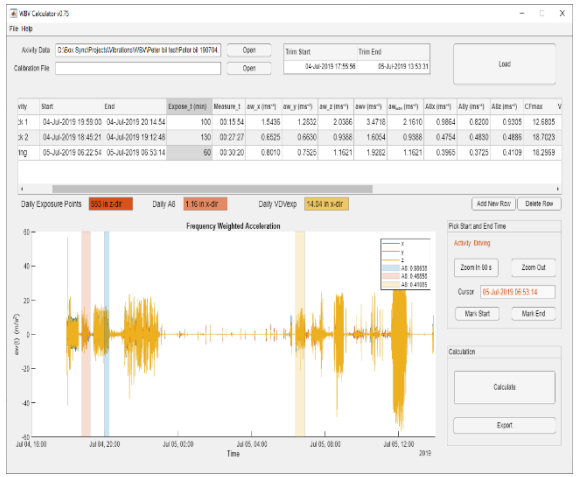
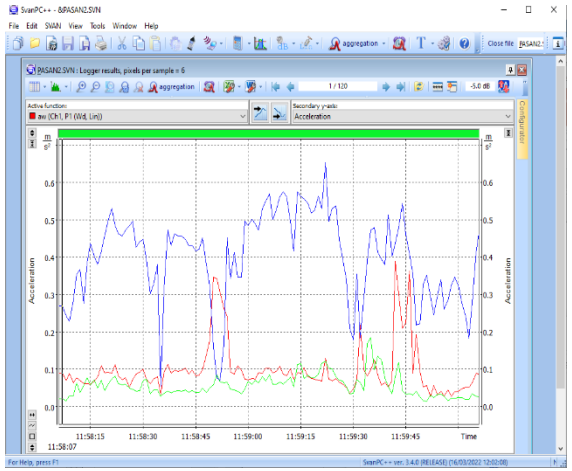
Field validation: Axivity AX3 based system vs Gold standard Svantek SV106

- Purpose:
  - Validating our system in real scenarios: compare AX3 based system in the field with a gold standard measurement system



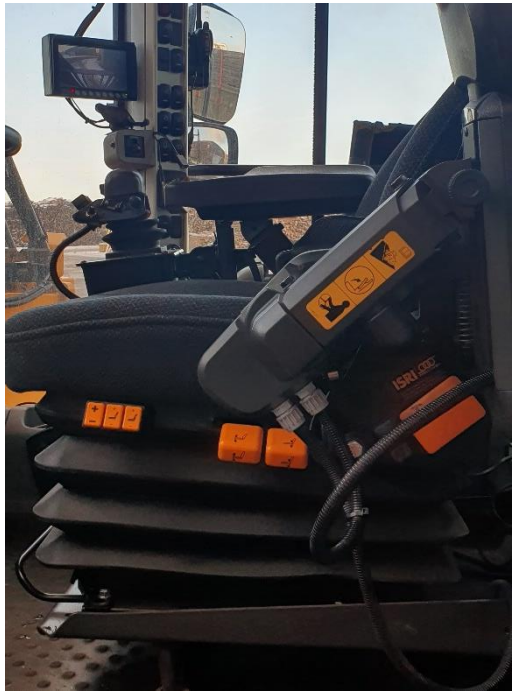
VS





Field validation: – a timber production company

- Multiple wheel-loaders
- A control-room (with low vibrations)
- 16 measurements: AX3s fixed on top of SV106's seat plate



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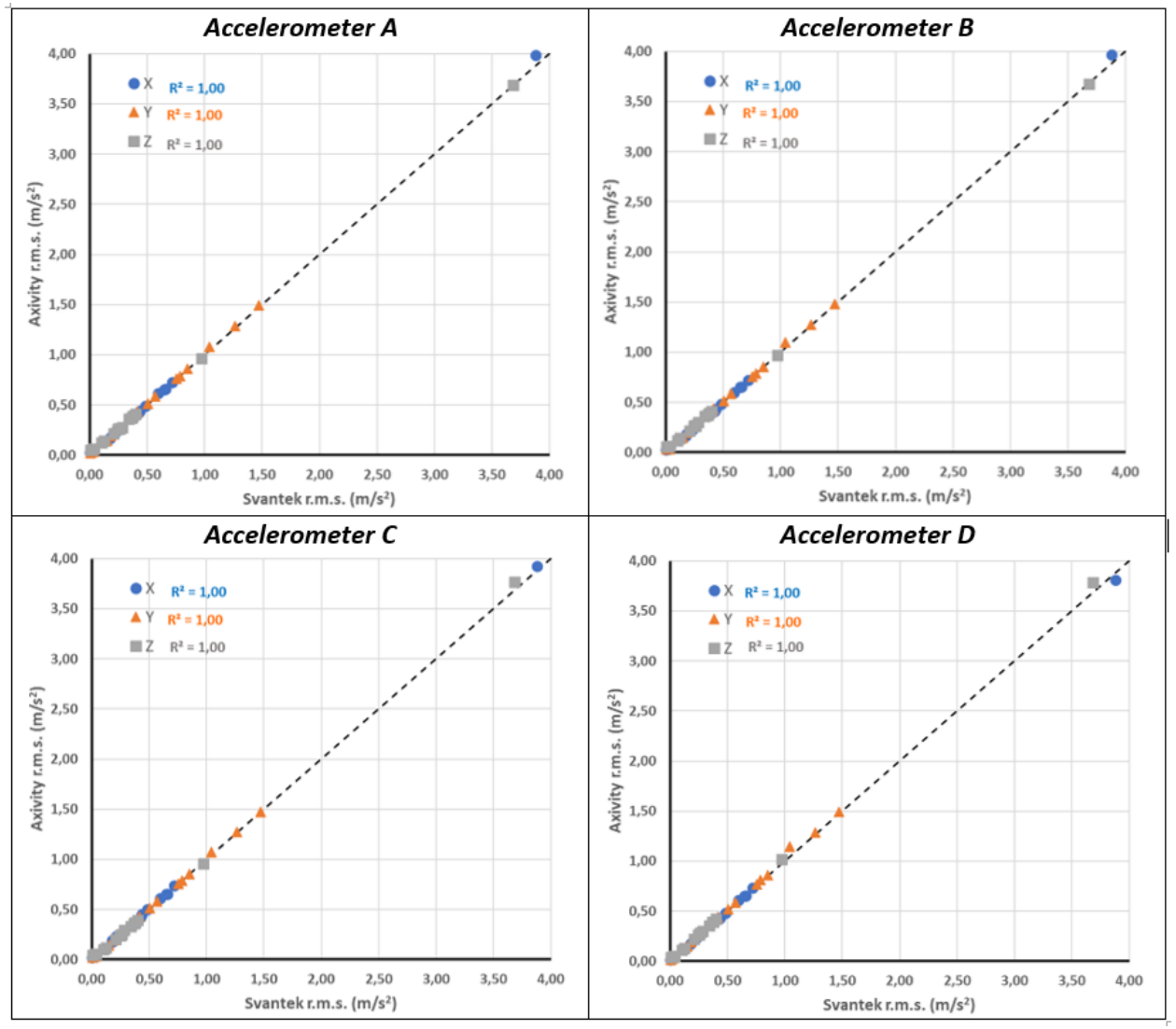
RMS (a_w) Comparison

- Very good correlation with Svantek
- Largest mean difference (bias) between AX3 and SV 106 was 0.02 m/s²



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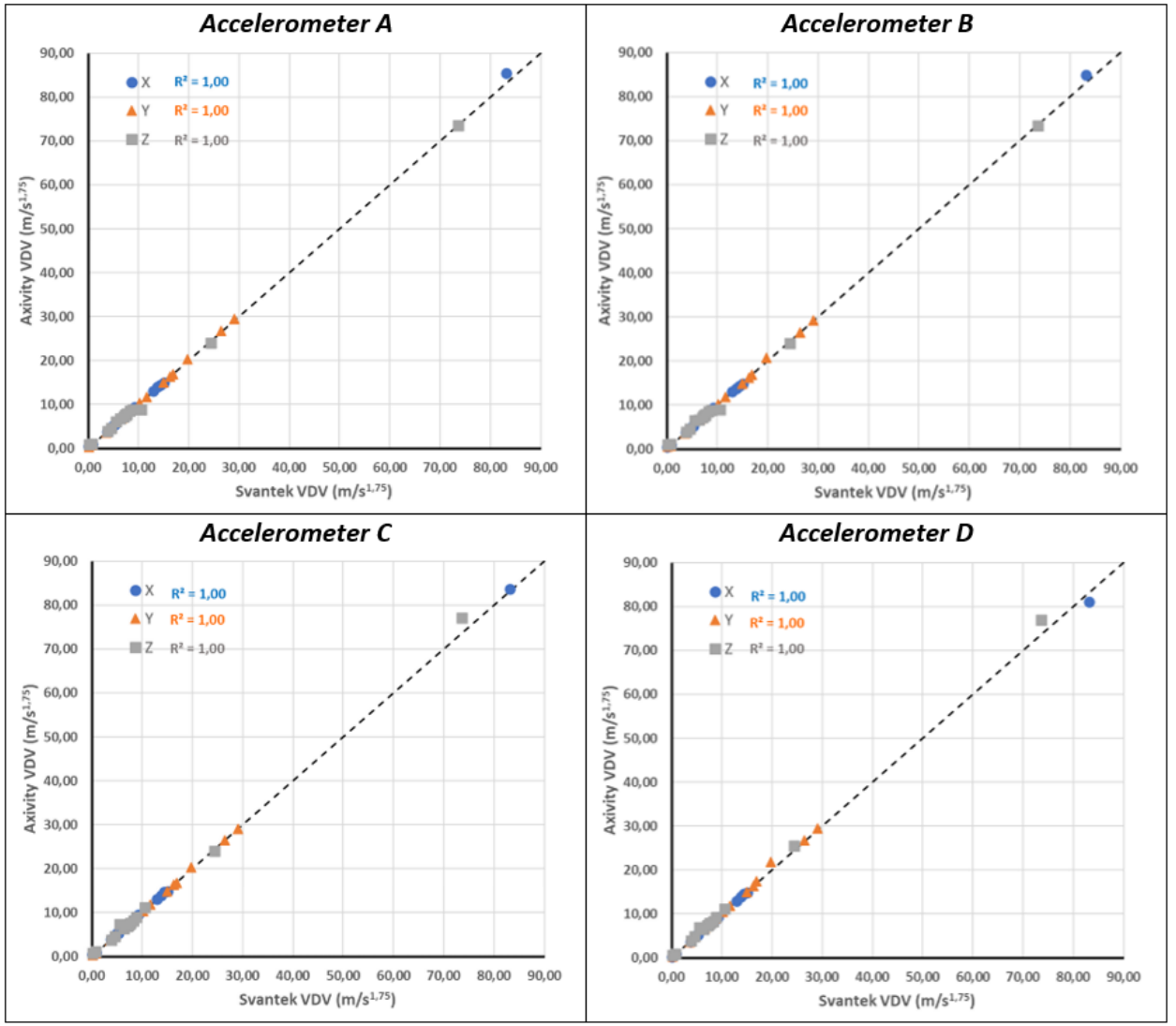
VDV Comparison

- Good correlation with Svantek
- Largest mean difference (bias) between AX3 and SV 106 was 0.56 $m/s^{1,75}$



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Final Remarks

- Field measurements with the AX3 and our software can be a sufficiently reliable method for risk assessments of WBV at work.
- A WBV measurement can be done fairly easily and at a low cost.

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