SPANK Industries – Vibrocore™ Test Conclusion

Frequency Analysis of Vibration Damping in MTB Handlebars

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Frequency Analysis of Vibration Damping in MTB Handlebars

Vibrocore™ is a proprietary, biodegradeable, complex foam core of precisely controlled density. Injected into Spank Industries handlebars, it reduces the harmful vibrations which can lead to hand-arm numbness and fatigue (HAVS), as well as arm-pump (CECS), while also increasing overall bar stiffness and fatigue life.

See Appendix A

What are these "harmful forces at work" in bicycles, what are their effects on the cyclist's body, and how does Vibrocore reduce these effects?

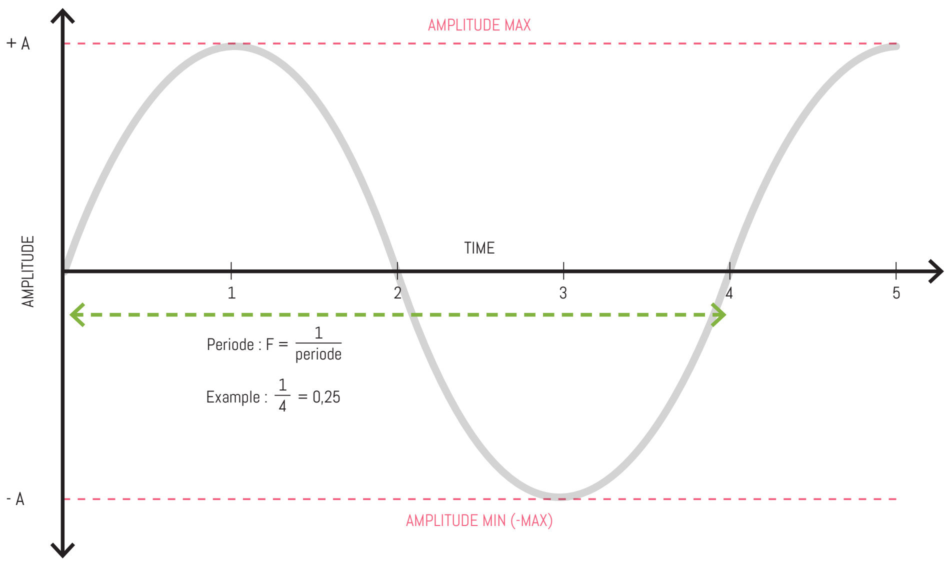
For the cyclist, as tires pass over the road, gravel, roots and rocks, our bikes shake, or vibrate, at different levels.

What is vibration?

For simplicity's sake, vibration can be explained as a transmission of mechanical energy. All energy travels as waves, whether sound, light, heat, or mechanical forces such as vibration. Waves can be measured as the result of two factors, frequency, or the time required for a single wave to complete its cycle, and amplitude, or the "height" of each wave.

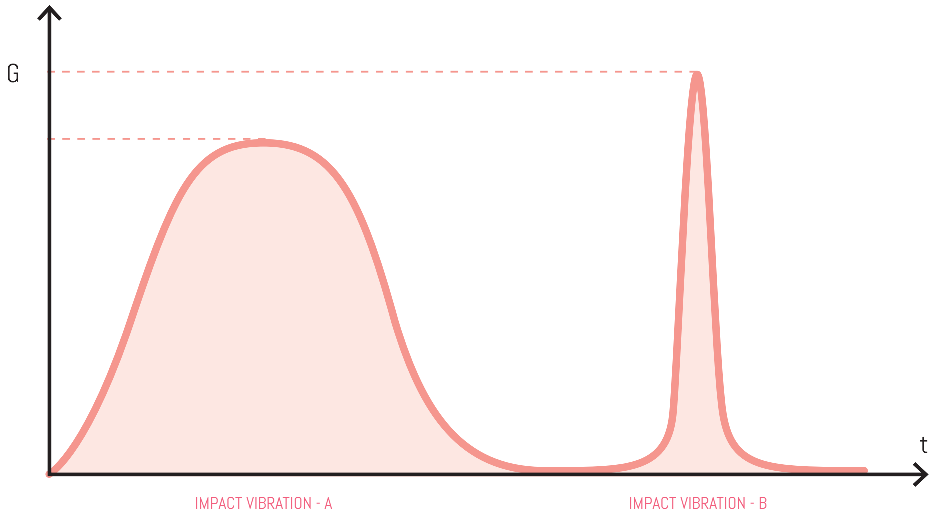
Frequency is measured in Hz, which is simply one wave cycle per second.

Amplitude on the other hand, is a value of acceleration, measured in G. The higher the amplitude, the greater the acceleration. 1G is the gravitational pull of the Earth.



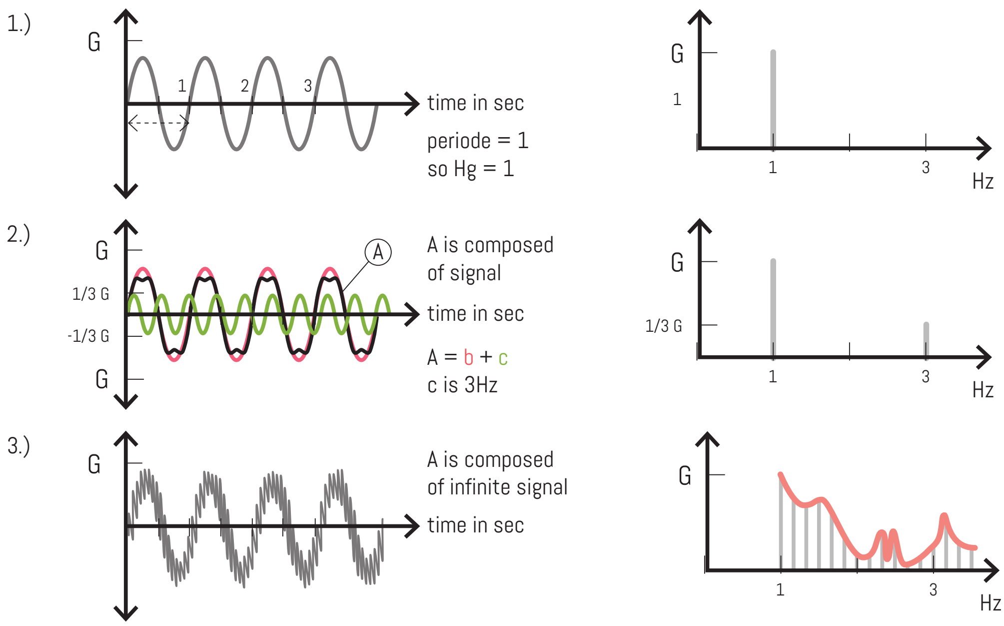
WHAT IS A WAVE?

The overall energy of a vibration is a product of frequency and amplitude. This vibrational energy is what the cyclist feels as it is transmitted to their hands. To simplify, we can view the energy contained by a signal as the surface area contained within the curve. In this case the vertical axis is amplitude (G), and the horizontal axis is frequency (Hz).



“B” HAS HIGHER AMPLITUDE BUT LESS ENERGY CONTENT INFO

Imagine if you will, two children of equal size, playing on a park swing. Both swing at a rate of one cycle every two seconds, or 0.5 Hz (1 cycle / 2 seconds = 0.5 Hz). The first child swings 1m (amplitude) into the air each cycle, while the second child swings 3m high. Obviously, you’d rather get hit by the child swinging 1m into the air, than the child with a 3m amplitude. The acceleration of the second child will be far greater, therefore more energy is contained within the 3m amplitude wave.



HOW TO GO FROM GRAPHS WITH time → TO GRAPHS WITH Hz →

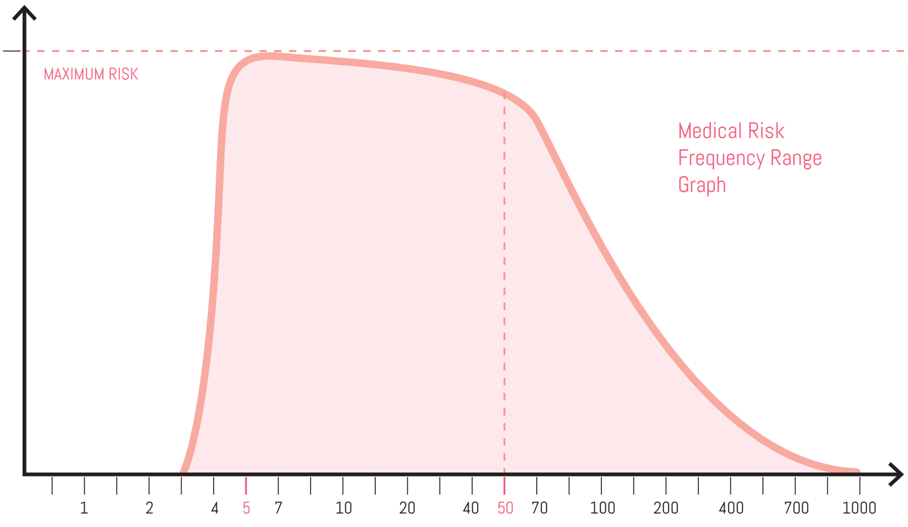
When an infinite number of energy waves, all with their own frequency (Hz) and amplitude (G), are combined to form a single signal, we can call this vibration.

We can call the mechanical forces (vibrations), which are transmitted through the bicycle to the cockpit, the G Input into the system (Gi). Bicycle suspension, frames, wheels, tires, bars and stems all absorb part of this vibrational energy. Reduce the level of vibration, and you increase comfort, endurance, and performance. However, despite our best efforts, inevitably part of this vibrational energy is transmitted to the rider’s hands. We will call this the G Output (Go).

What are the negative effects of vibration on cyclists?

Aside from the obvious reduced sense of stability and control in high vibration circumstances, riders also tend to grip their bars more tightly as vibration increases (commonly known as "death-grip"). It's the combination of tight grip, and sustained vibration (within certain frequencies), which has been proven to cause medical conditions such as HAVS, VWF, CECS, and so on. These recognized syndromes are not unique to cycling. In fact they have been studied extensively with relation to motorsports, construction power tools, and even dentistry. See Appendix B

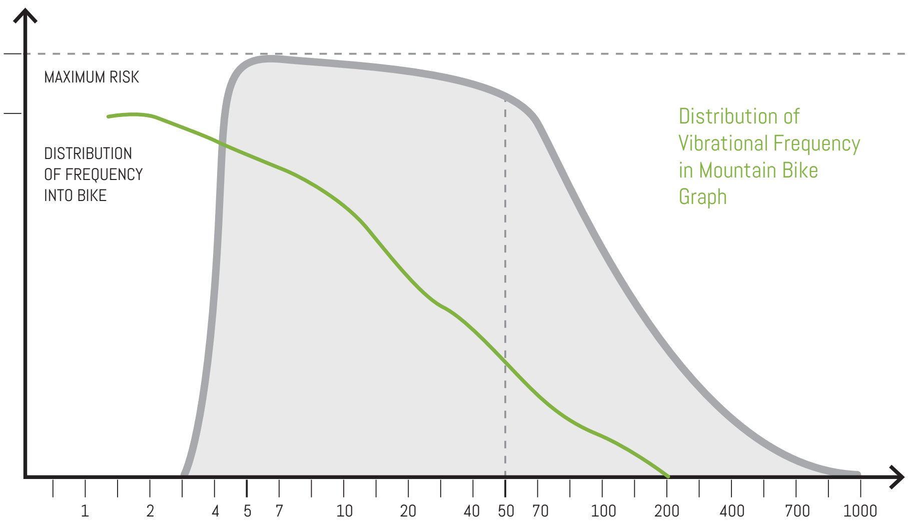
Medical studies have shown that risk of vibration induced ailments exists from prolonged exposure to vibration between 5 and 2000 Hz, with the greatest risk of hand-arm numbness and other severe conditions at lower frequencies, between 8-50 Hz. Negative effects diminish rapidly at frequencies exceeding 16Hz. The vibration "medical risk frequency range", can be graphed out quite simply with Medical Risk on the vertical axis and Vibrational Frequency on the horizontal.



RISK GRAPH (MEDICAL)

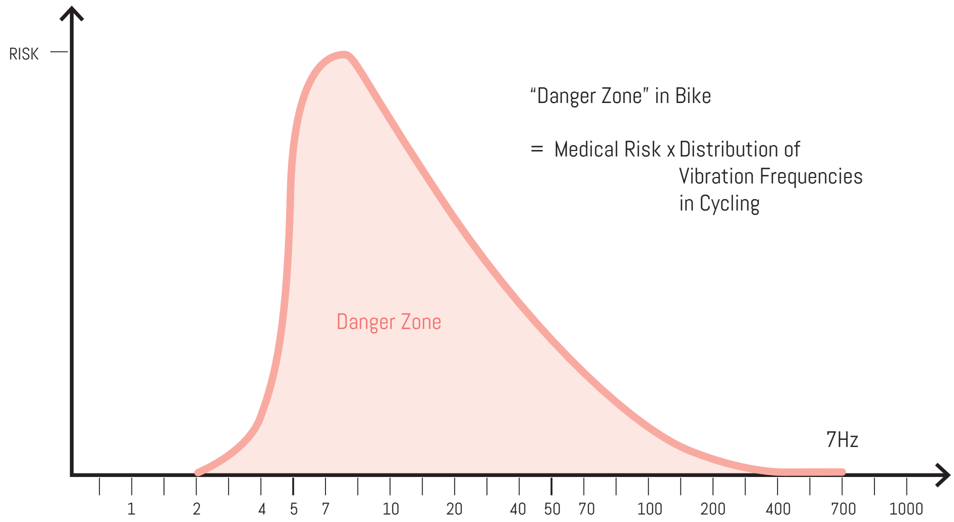
What vibrational frequencies are present in bicycles?

Many studies (see appendix C) using accelerometer sensors, have been conducted to show the frequencies of vibration transmitted to cyclists through their bicycles, via three contact points, pedals, handlebars, and saddles. When we examine the vibrational forces at work in cycling, specifically mountain biking, we see a common range of roughly 2 Hz to 200 Hz, and most commonly in handlebars between 5 Hz to 50 Hz. This is exactly within the "medical risk frequency range" outlined by doctors. We can infer that during cycling low frequency vibrations will be more regular and of higher amplitude, while high frequency vibrations will be far less common, and of lower amplitude.



RISK GRAPH (MEDICAL)

The Vibrational “Danger Zone” specific to cyclists, is thus a product of “Medical Risk Frequency Range” X “Distribution of Vibration Frequencies in Cycling”.

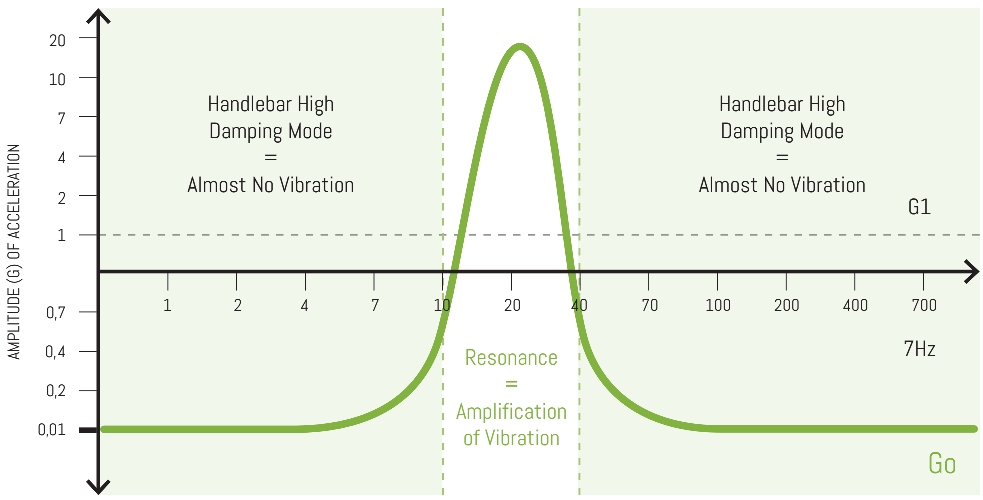


RISK GRAPH (MEDICAL)

Compounding this problem, is the effect of “Resonance”. While bike components actively work to absorb and reduce vibrations at certain frequencies, the same components can actually increase vibrations at other frequencies. This is a common effect seen in handlebars.

If we revisit the two children on the swing, and now we give them a push, we can see this effect at work. Push the first child at random points in their cycle, and you’ll most likely reduce the child’s amplitude. However, if you push the second child each time at the peak of their cycle, their amplitude (acceleration) will increase with each push. That’s resonance at work in a positive way.

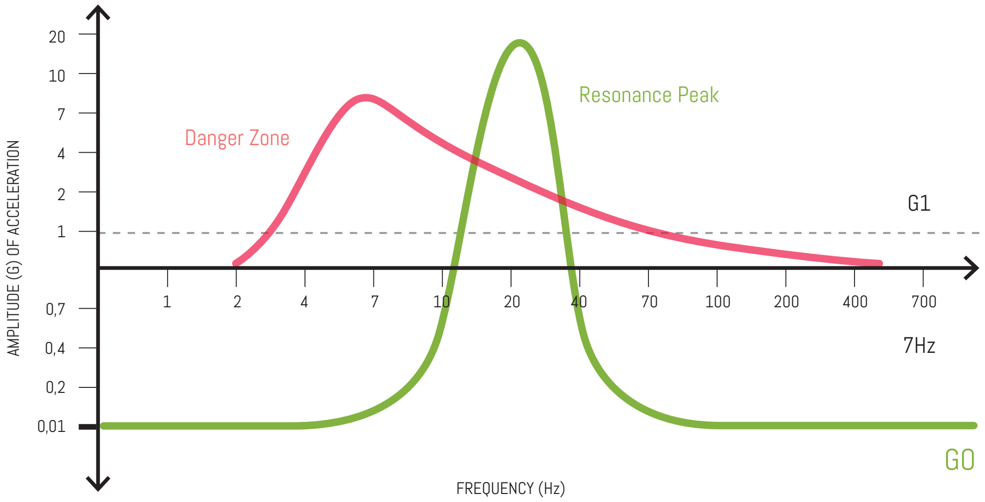
All objects have natural resonance frequencies specific to their geometry and construction. When mechanical forces entering into the system, vibrate at the same natural frequency, the amplitude of vibrations can be increased by resonance.
All handlebars tested tend to act as dampers, reducing the amplitude of vibrational waves at low frequencies (between 1-8 Hz), and also at higher frequencies (usually over 30 Hz). At these very low and higher frequencies, handlebars are in damping mode. However, certain frequencies exist (most commonly 15-25 Hz), where handlebars cease to dissipate vibration, and begin to act as resonators. At these frequencies the vibration transmitted from the bicycle works in resonance with the handlebar, actually increasing the amplitude of vibrational energy waves transferred to the rider’s hands.



TYPICAL BAR RESPONSE

Some handlebars show this effect more so than others, some at higher frequencies, and some at lower. When handlebars are in damping mode, most of the vibrational energy will dissipate, making its effect on the human body limited. However when handlebars are in resonance mode, harmful vibrations transmitted to the rider's hands are increased by the specific geometry and construction of each handlebar. This has been shown for all handlebar types, whether alloy, steel, or carbon material, and/or 25.4mm, 31.8mm, or 35mm diameters. This study puts particular attention on these resonance peaks, where the handlebar amplifies vibration rather than damping it.

The Vibrational "Perfect Storm" occurs when vibrations with high amplitude and sustained frequency within the danger zone for hand-arm numbness (8-50 Hz), fall into the natural resonance frequency range of the handlebar in question. This is where cyclists are at the greatest risk. In laboratory tests, recreating this effect can be quite violent and destructive.



TYPICAL BAR RESPONSE

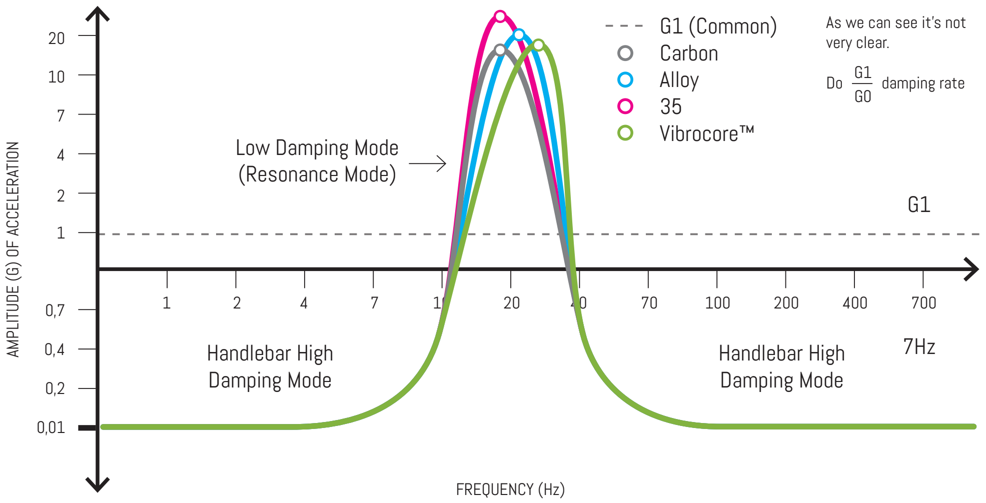
Reducing the amplitude of vibrations transmitted to the rider's hands is obviously very important to reducing vibrations' harmful effects. However, if we can physically move the natural resonance frequency of a handlebar into a higher frequency range, it could be equally important for two reasons. First, higher frequencies of vibration are less present in MTB, and second, higher frequencies of vibration are proven medically less harmful.

How did Spank test these factors, and how does Vibrocore reduce the harmful effects of vibration on riders?

Spank Industries, in cooperation with SGS Labs, developed a series of tests, with the goal of quantifying the vibrational characteristics, damping rates, and resonance effects of various handlebar types. An acceleration test machine fixes the handlebar in a typical riding orientation. This machine can move upward and downward at controlled frequencies, and at controlled acceleration (G input or Gi). Thus the frequency and amplitude of the vibration can be controlled precisely. The handlebar is loaded with weights at the barends, which are representative of the rider's weight on the bar. Sensors are mounted at each barend, to record resulting vibrations which would be transmitted to a rider's hands (G output or Go).

The test machine is set to keep a constant amplitude (Gi), and vary slowly from a low frequency (Hz) to higher frequencies by adjusting the rate at which it vibrates, while sensors record vibrational data at the barends (Go). Here we can see clearly that even with a fixed input amplitude (Gi), the amplitude of vibrations exiting the system through the handlebars (Go), changes greatly as frequency varies, and peak at a distinct vibrational frequency range. This is the handlebar's natural resonance frequency.

See Appendix D

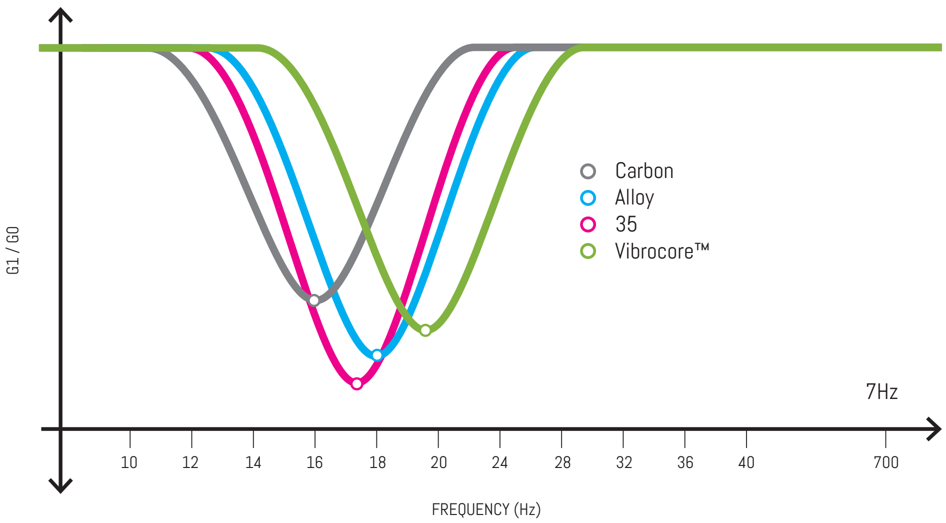


HANDLEBAR RESONANCE FREQUENCIES

What is damping?

Damping is a reduction in the amplitude of an oscillation (in this case vibrational energy waves), as a result of energy being drained from the system to overcome resistive forces. Thus, Damping Rate is a measure of an object ability to reduce the amplitude of vibrations. If an object has a high damping rate at a given frequency, almost all vibrational energy which enters the system will be absorbed or dissipated.

The Damping Rate of any handlebar is a calculation of the G input (Gi) entered into the system by the bicycle or test machine, divided by the G output (Go) transmitted to the riders hands or test sensors. Gi/Go= Damping Rate.
The damping rate of each handlebar at different frequencies can be graphed with Gi/Go on the vertical axis, and frequency (Hz) on the horizontal axis. Here we can see a clear trend in all handlebars, showing high damping rates at very low frequencies, and also at high frequencies, but a very distinct reduction in damping rate at the bars resonance peak frequency. Normally that exists at a frequency of roughly 12-25 Hz.



DAMPING RATE GRAPH

To accurately gauge the level of vibrational syndrome risk to the rider for each bar type, we must take into account:

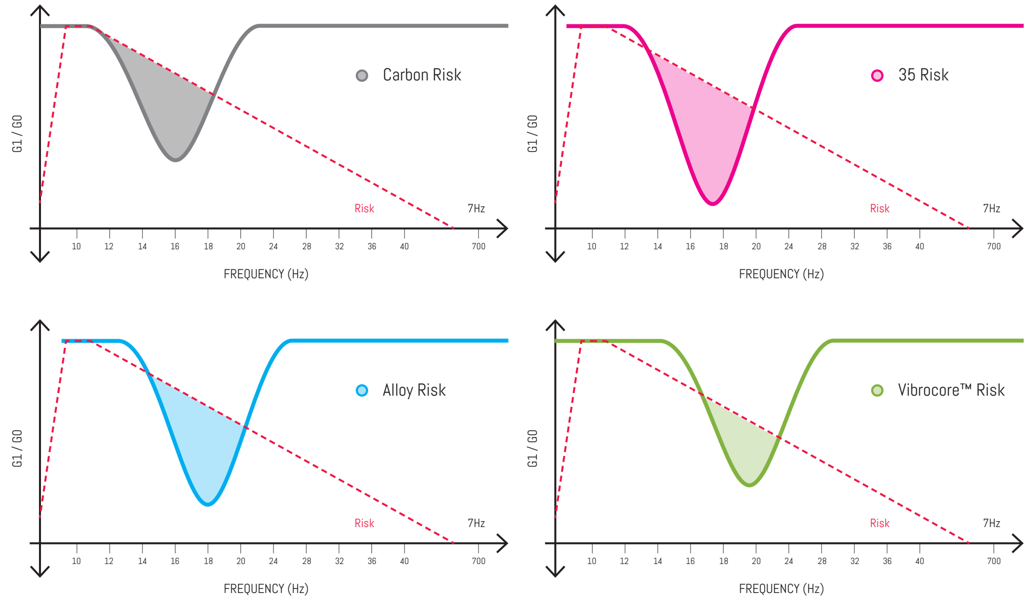
- Medical risk vibrational frequency range
- Observed distribution of vibrational frequencies in bicycle handlebars
- Damping Rate of handlebars (or more accurately, the resonance frequency range where each bar ceases to damp vibrations and may amplify them).

The risk of vibrational syndromes to the rider for each handlebar type can be calculated as the area of the graph that is contained within both the "danger zone" frequency range, (the result of medical risk frequency range X vibrational frequencies observed in bicycles), and the frequency range where Damping Rate reduces due to resonance, and the amplitude of vibrations increase.

When we examine a traditional alloy 31.8mm handlebar, it's clear that the damping rate is reduced dramatically (in resonance mode). This occurs within normal cycling vibrational frequencies, and the majority of vibrational energy that transfers through to the hands falls within the medical "danger zone". . See appendix E – test data 31.8mm alloy.

The same is true for carbon bars to a certain degree. Although a carbon handlebar's damping rate is reduced less than standard alloy bars when in resonance mode, the resonance frequency range is found at lower frequencies. So, most of the vibrational energy that transfers to the rider's hands still falls within the risk curve. We must keep in mind also that these lower frequency vibrations are more common in cycling. See appendix F – test data carbon.

Tests with larger diameter bars, such as the recent 35mm standard, show the greatest reduction in Damping Rate when in resonance mode, and a low resonance frequency range, both meaning vibrational risk issues are heightened. 35mm diameter handlebars showed the lowest Damping Rate, and highest transmission of harmful vibrations to sensors in these tests. See appendix G – test data 35mm



DAMPING RATE + DANGER ZONE

Vibrocore bars act in two important ways to reduce negative vibration.

- First, the measured reduction in Damping Rate during resonance mode is significantly less than other bar types tested. In every bar tested, Vibrocore reduces resonance peaks (and drop in Damping Rate) by 15-20% or more.
- Vibrocore also effectively moves the resonance frequency range of each handlebar to higher frequencies, by 25% or more. This not only pushes some of the vibrational frequencies transferred to the hands out of the most medically dangerous range, but also into a range that is less commonly seen in cycling.
- The combined effect is at least a 30% reduction in harmful vibrations transferred to the rider's hands, when compared to other bar types tested.

**See appendix H – test data Vibrocore*

What other benefits can be quantified in Vibrocore handlebars?

Aside from the advantage of reduced harmful vibrations, Vibrocore Handlebars show several other properties, which are beneficial to cyclists.

Stiffness: Handlebars are often measured for "performance" by their level of stiffness. With a stiff handlebar, energy exerted by the rider is not lost to handlebar flex, and goes into maneuvering the bicycle more efficiently. Also under heavy load situations like landing a drop, or taking off the lip of a jump, a stiff handlebar feels consistent, rather than flexing under load, which can make the bicycle feel less stable. As handlebar comfort has become a topic of consideration, some brands have designed more flex into handlebars, trying to find a good compromise between stiffness and comfort, while not excelling at either. The core fill in Vibrocore bars actually acts to reinforce the handlebar, making it test and feel stiffer, while reducing the vibrations that are normally a factor of discomfort. It's the best of both worlds.

Fatigue Life: A second major benefit to cyclists, is a marked increase in fatigue life, when the Vibrocore system is added to any handlebar. Reduced flex, and the internal structural reinforcement offered by Vibrocore, has been tested to raise fatigue test results by up to 400% over the same bar without Vibrocore. Increased fatigue life means a safer product that will last longer, benefiting both the rider and environment.

Environmental Responsibility: Vibrocore handlebars are exclusively manufactured with metallic alloy base materials, such as aluminums, which are infinitely recyclable, use less energy to produce, and contain less harmful chemicals than carbon alternatives. In conjunction with Spank Industries' proprietary Dual XGT Taper technology and CNC Bending process, Vibrocore now makes possible alloy handlebar designs which can exceed the benefits of carbon bars, at very competitive weights.

Vibrocore itself as a material, is chemically inert, and contains no carcinogens. Vibrocore is biodegradable over time (Two species of the *Ecuadorian fungus Pestalotiopsis* are capable of biodegrading Vibrocore foam in aerobic and anaerobic conditions such as found at the bottom of landfills),

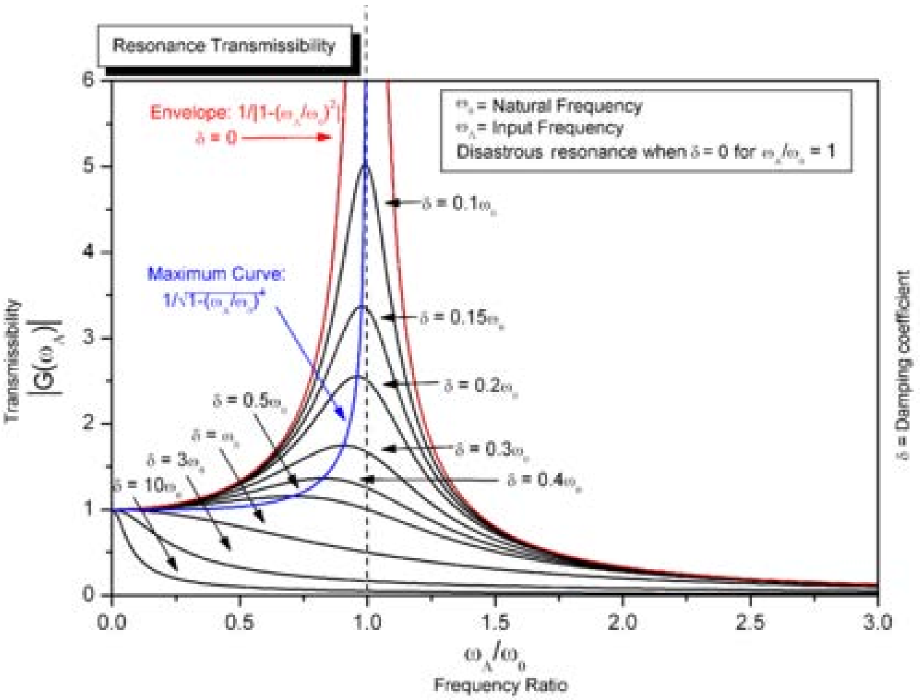
Where many foam injection processes are harmful to the Earth's atmosphere, due to the use of dangerous propellant gasses such as CFCs, the Vibrocore process uses no volatile gases, and poses no risk to the environment.

Join the Earthball Riders Foundation for more info on this and other environmental concerns in the bike industry.

www.earthballriders.org

APPENDIX A

MEDICAL EXPLANATION OF ARM-PUMP (CECS)



Arm-pump (also known as CECS or Chronic Exertional Compartment Syndrome), is a condition which affects men and women equally, commonly seen in endurance and motor sports where individuals are exposed to sustained low frequency vibration. Arm-pump refers to a state of acute pain and loss of muscle performance, caused by excessive swelling of muscles in the forearm. Muscles are bundled in a strong, but relatively inflexible membrane called fascia. Muscles can grow in volume up to 20% as blood rushes in to provide energy during periods of exertion. As the fascia membrane is not able to stretch to accommodate this swelling, the muscle becomes more and more tightly bound, inducing pain and inhibiting blood flow which leads to muscle underperformance and over-fatigue.

HAVS (Hand-Arm Vibration Syndrome) is the medical term for symptoms caused by vibration damages that may occur in the fingers, hands and arms with prolonged exposure to vibrating tools or machinery. Vibration injuries are divided into three subgroups: neurological disorders, vascular and musculoskeletal.

Resonance - In physics, resonance is a phenomenon in which a vibrating system or external force drives another system to oscillate with greater amplitude at a specific preferential frequency. Increase of amplitude as damping decreases and frequency approaches resonant frequency of a driven damped simple harmonic oscillator.

APPENDIX B

STUDIES LINKING VIBRATIONS TO HAVS / CECS:

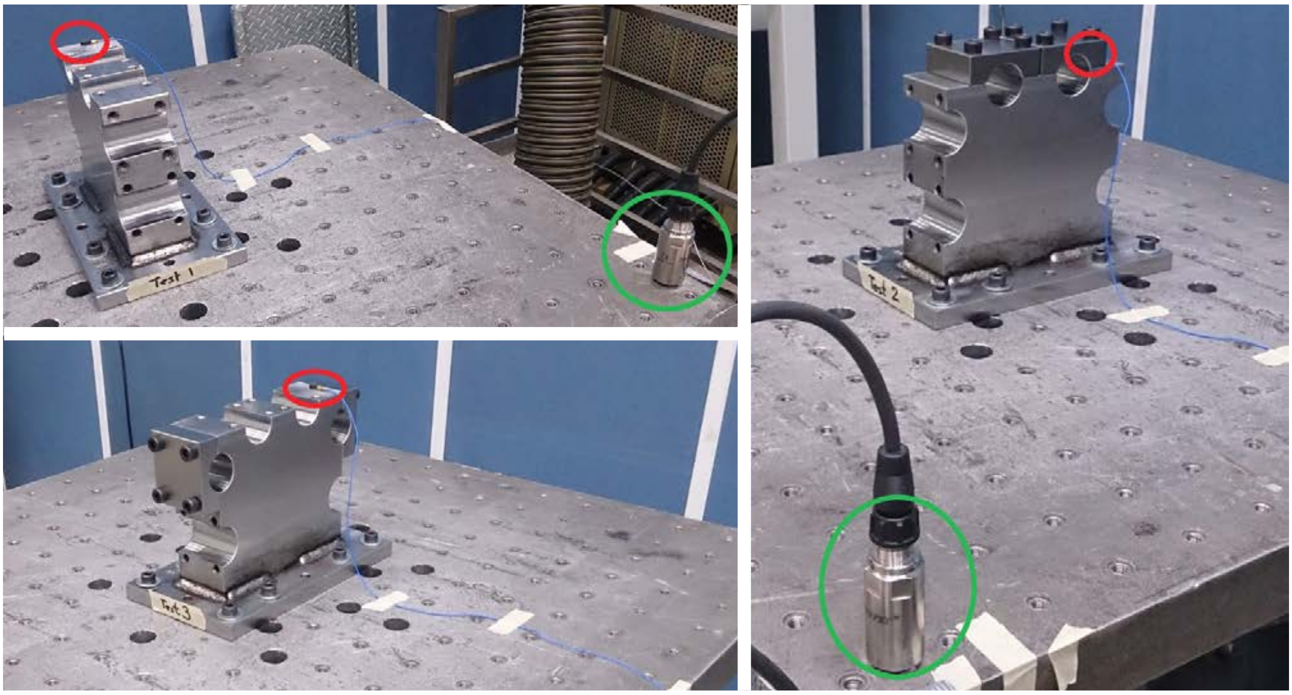
https://en.wikipedia.org/wiki/Vibration_white_finger
http://patient.info/health/hand-arm-vibration-syndrome-leaflet
https://www.ncbi.nlm.nih.gov/pubmed/19609523
https://academic.oup.com/rheumatology/article/44/11/1442/1784705/Chronic-compartment-syndrome-an-important-cause-of
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.526.8754&rep=rep1&type=pdf
https://www.ncbi.nlm.nih.gov/pubmed/7371623
https://www.ncbi.nlm.nih.gov/pubmed/1917073
https://www.ncbi.nlm.nih.gov/pubmed/6696700
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1009620/
https://www.ncbi.nlm.nih.gov/pubmed/23201635
https://www.ncbi.nlm.nih.gov/pubmed/9258704
https://www.ncbi.nlm.nih.gov/pubmed/18208429
https://www.ncbi.nlm.nih.gov/pubmed/22588395
http://www.mayoclinic.org/diseases-conditions/raynauds-disease/basics/causes/con-20022916
http://www.dermnetnz.org/topics/vibration-white-finger-hand-arm-vibration-syndrome/
http://www.legislation.gov.uk/uksi/2005/1093/pdfs/uksi_20051093_en.pdf
https://www.ccohs.ca/oshanswers/diseases/raynaud.html
http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=32355
http://www.hse.gov.uk/vibration/hav/casestudies/mhav-carlwest.htm
https://www.cdc.gov/niosh/mining/works/coversheet1258.html
http://www.hse.gov.uk/pubns/indg175.pdf
http://www.hse.gov.uk/vibration/wbv/ports.pdf
http://www.hse.gov.uk/pubns/indg242.pdf
http://link.springer.com/article/10.1007%2Fs004200050182

APPENDIX C

STUDIES ON VIBRATION INTO BICYCLES

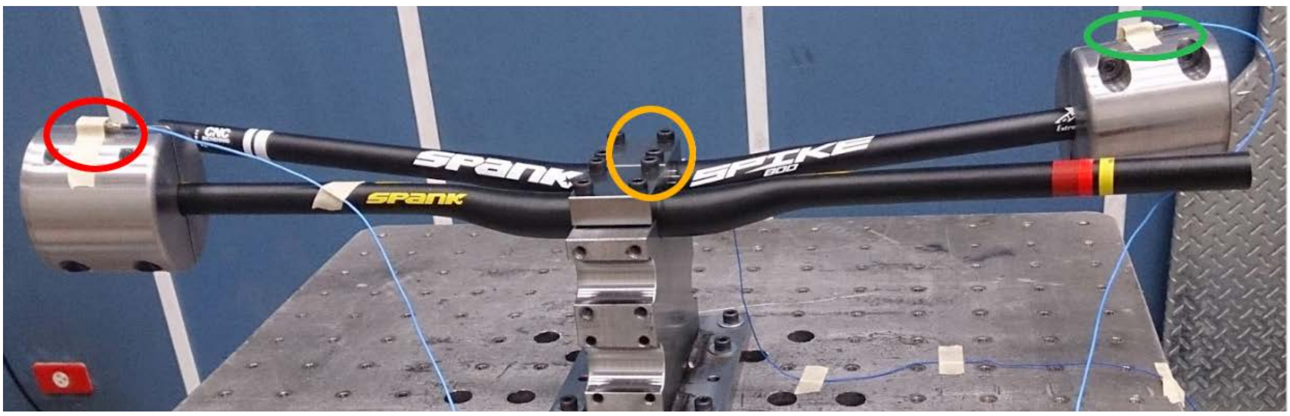
http://www.sciencedirect.com/science/article/pii/S1877705814005670
https://www.researchgate.net/publication/236657039_Hand-arm_vibration_in_cycling
https://www.researchgate.net/publication/225528193_Effectiveness_of_vibration_damping_with_bicycle_suspension_systems
http://www.worldcat.org/title/bicycling-science/oclc/265448851
http://www.icrepq.com/icrepq-08/344-minazara.pdf
https://mitpress.mit.edu/books/bicycling-science
http://www2.uwe.ac.uk/faculties/FET/Research/cts/projects/reports/wc2013_parkin.pdf
https://ir.library.oregonstate.edu/xmlui/handle/1957/32759
https://www.ncbi.nlm.nih.gov/pubmed/17557052
http://www.sciencedirect.com/science/article/pii/S1877705814005773
https://www.ncbi.nlm.nih.gov/pubmed/10464694
http://onlinelibrary.wiley.com/doi/10.1111/j.1747-1567.2004.tb00161.x/abstract
https://core.ac.uk/download/pdf/10192890.pdf
http://www.sandv.com/downloads/0707cham.pdf
http://mecano.gme.usherb.ca/~jmdrouet/velus/assets/2004_imac_xxii.pdf

APPENDIX D - SGS LABORATORY TESTS



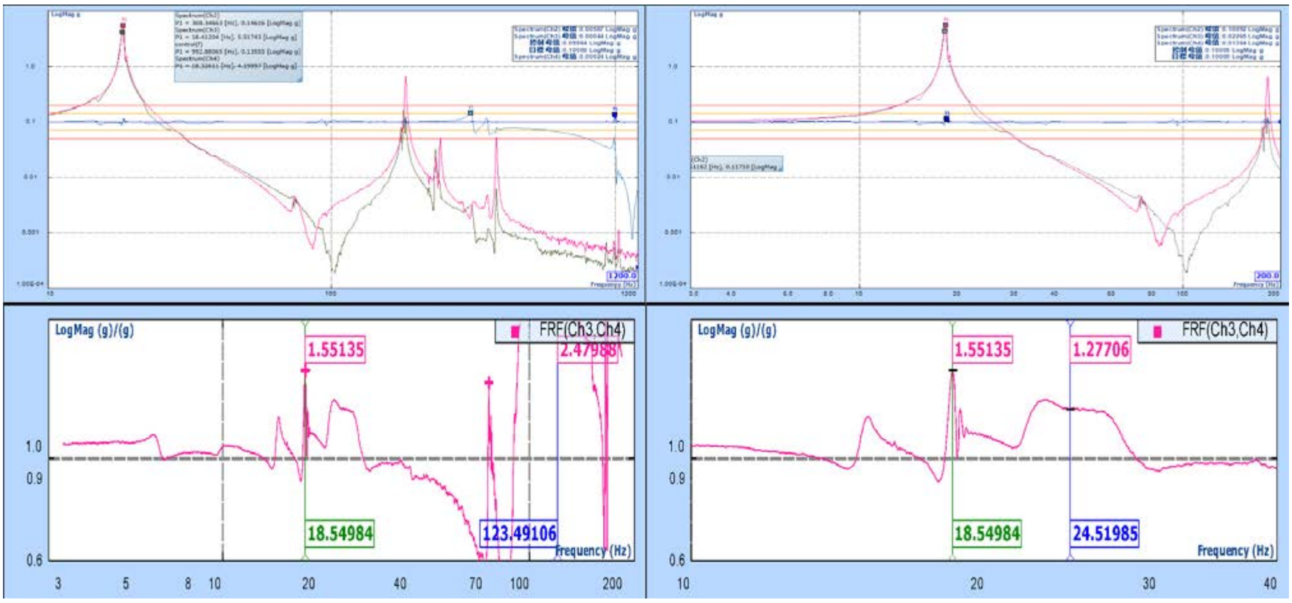
SENSOR G(i) CONTROL SENSOR

SENSOR G(i) SENSOR G(o)



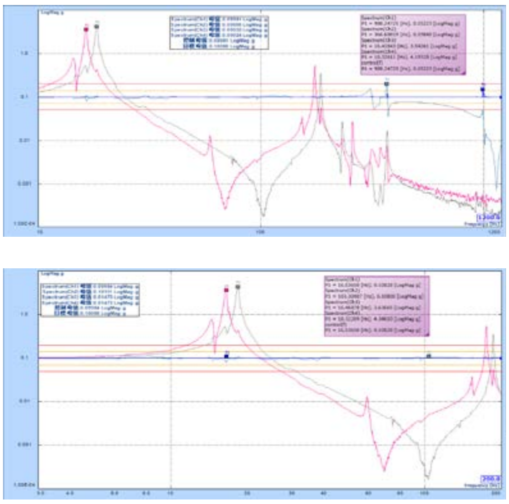
SENSOR G(i) SENSOR G(o bar 2) SENSOR G(o bar 1)

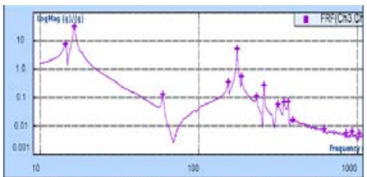
APPENDIX E - 31.8MM ALLOY TEST DATA



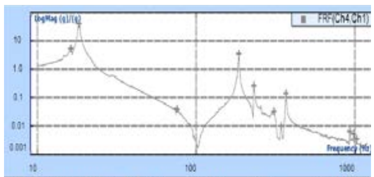
SPIKE VIBROCORE™ VERSUS SPIKE NON-VIBROCORE™

APPENDIX F - CARBON TEST DATA





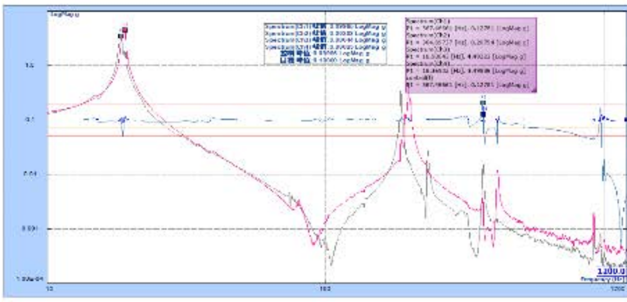
Index	頻率 (Hz)	振幅(V)	相位	Q	相位斜率
1	14.437	7.8177	-55.201	24.777	-1
2	16.418	33.232	-147.39	37.636	-1
3	59.149	0.13102	-19.029	50.187	-1
4	153.23	0.36321	-149.81	73.589	1
5	174.26	5.3055	-166.27	88.824	1
6	186.06	0.56595	-179.54	89.055	-1
7	230.72	0.11273	14.872	44.106	-1
8	257.53	0.27146	120.08	101.64	1
9	314.91	0.060137	-123.41	21.895	-1
10	343.37	0.069912	-152.99	40.947	-1
11	366.61	0.07283	78.093	80.223	-1
12	391.42	0.016571	149.24	6.8296	-1
13	617.6	0.0081743	164.95	20.665	1
14	848.88	0.0058808	-169.97	40.259	-1
15	923.44	0.0065183	108.59	40.44	-1
16	1028.3	0.005622	14.475	32.963	-1

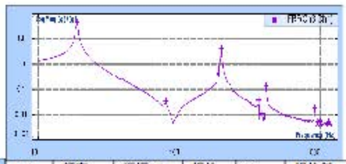


Index	頻率(Hz)	振幅(V)	相位	Q	相位斜率
1	16.228	5.4509	-23.81	21.231	-1
2	18.283	40.477	-133.94	38.057	-1
3	75.79	0.039503	142.28	15.389	1
4	185.62	3.558	151.07	97.306	1
5	231.26	0.26443	120.32	94.394	1
6	309.79	0.03314	125.24	14.866	-1
7	343.37	0.010037	-157.1	68.374	-1
8	367.47	0.14212	-150.19	82.639	-1
9	929.94	0.0065048	-137.93	99.194	1
10	983.64	0.0053397	102.77	98.957	-1
11	1028.3	0.0035391	136.93	77.942	1

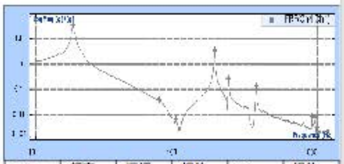
COMPETITOR CARBON VERSUS SPIKE VIBROCORE™

APPENDIX G - 35MM TEST DATA



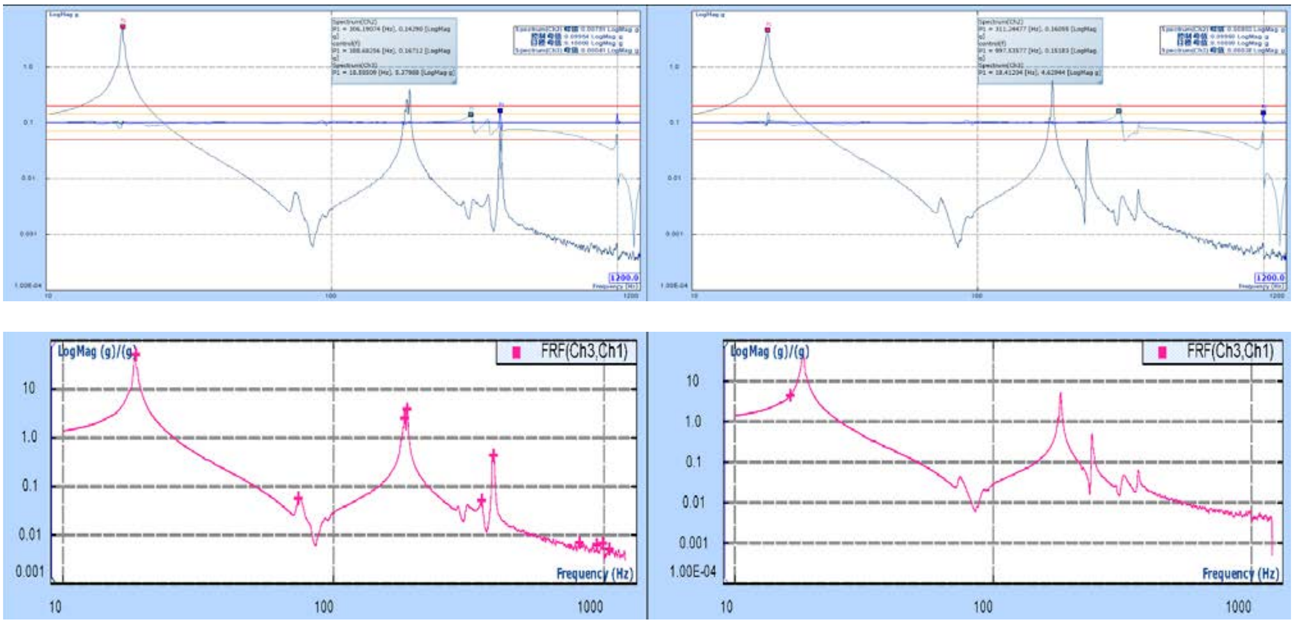


Index	频率 (Hz)	振幅(V)	相位	Q	相位斜率
1	18.892	46.919	-142.13	35.985	-1
2	79.791	0.035193	58.054	21.447	-1
3	197.72	4.3182	-156.82	90.05	-1
4	364.04	0.03825	98.465	74.724	-1
5	380.59	0.010926	-142.48	18.263	1
6	413.05	0.13643	-179.02	98.587	-1
7	914.84	0.019192	21.501	99.753	-1
8	960.9	0.0052164	157.63	22.465	-1
9	992.88	0.005541	-145.23	25.794	-1



Index	频率 (Hz)	振幅 (V)	相位	Q	相位斜率
1	18.326	35.206	-118.6	39.238	-1
2	75.26	0.04032	172.13	17.64	1
3	98.947	0.0068234	-123.53	21.873	-1
4	185.62	3.5038	143.54	98.528	1
5	231.8	0.27591	-55.706	90.442	1
6	365.75	0.13621	-161.04	87.419	-1
7	914.84	0.0089739	165.13	103.23	1
8	963.15	0.0081916	10.261	82.929	-1
9	990.56	0.0032056	169.52	31.864	1

APPENDIX H - VIBROCORE TEST DATA



SINGLE CHARGE VERSUS DOUBLE CHARGE