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Vibration resistance study of wire bonds for EV battery packs applications

Presented by

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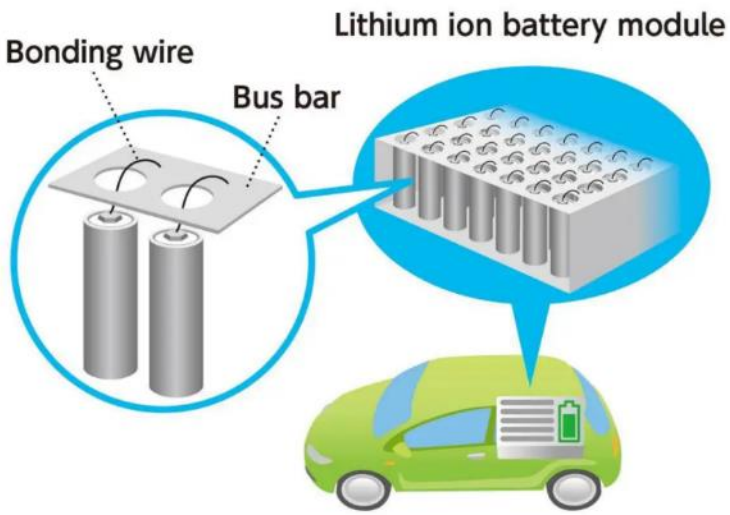
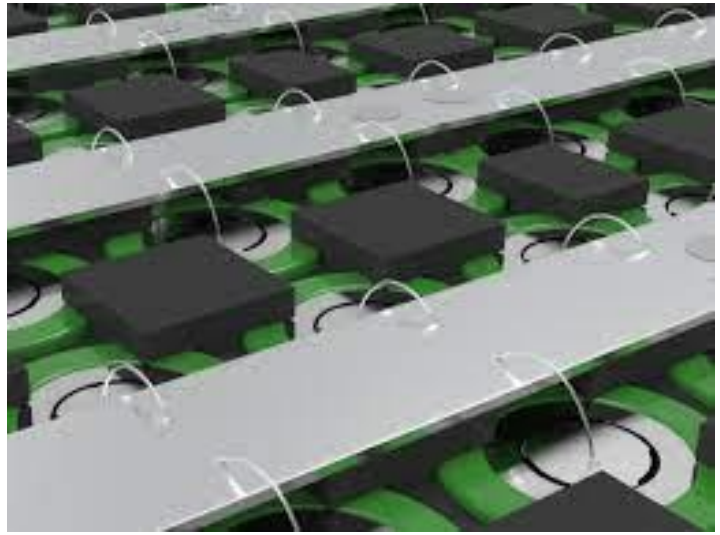
Background

Ultrasonic wire bonding is currently used for interconnection if cylindrical-ion cells in EV battery packs





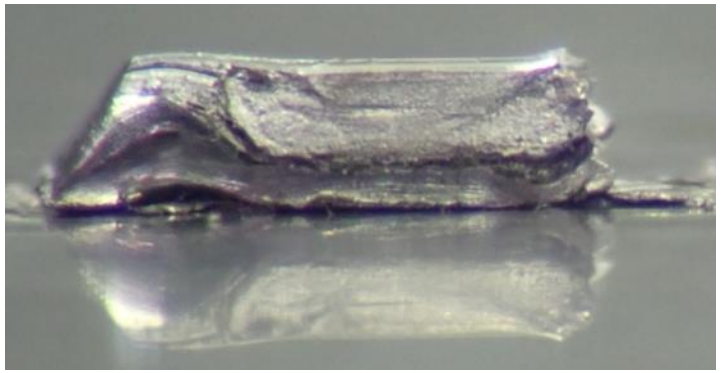
Wire bond technology has long been used for semiconductors because of its inherent flexibility, considered a major advantage over other connecting methods
However, there are concerns about the vibration resistance of wire bonds in EV battery packs and other open-air applications,
because unlike semiconductors, these are not encapsulated by buffer materials such as resin or mold compound in most cases.

Background

When you drive uneven street or sudden stop / start, you may have concerns whether occur any wire break due to fatigue caused by vibration.

Uneven street

Sudden start / stop



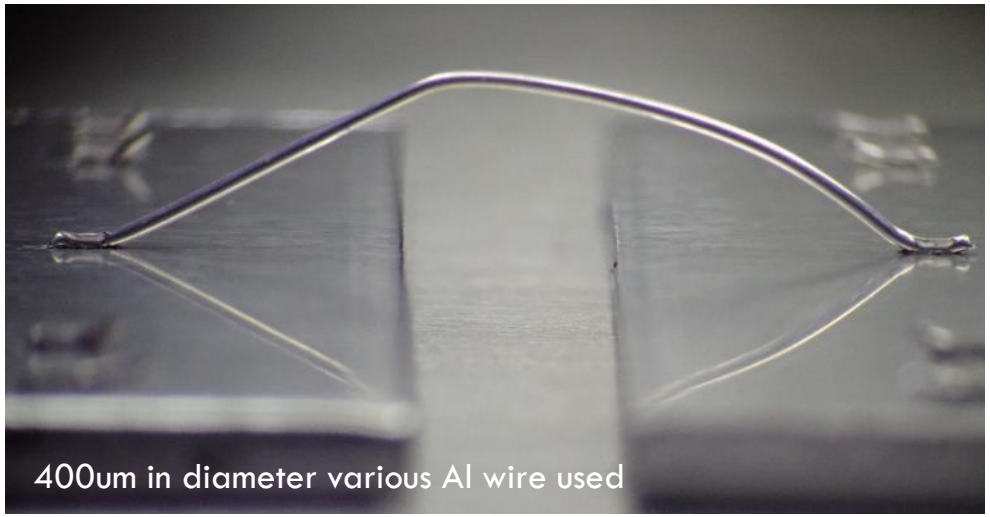
Wire break at neck

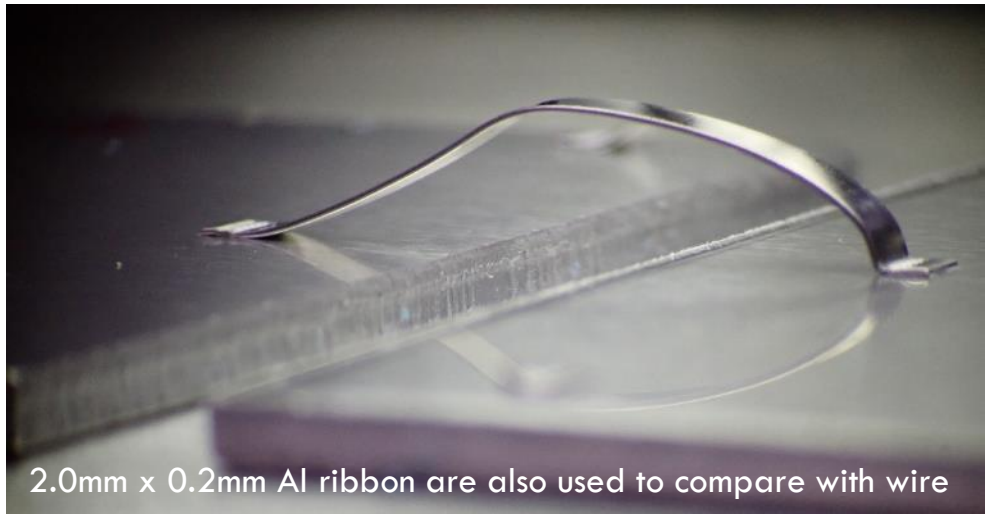
Vibration tests of wire bonds using test equipment developed for this purpose were completed and results are hereby presented.

What we are going to present

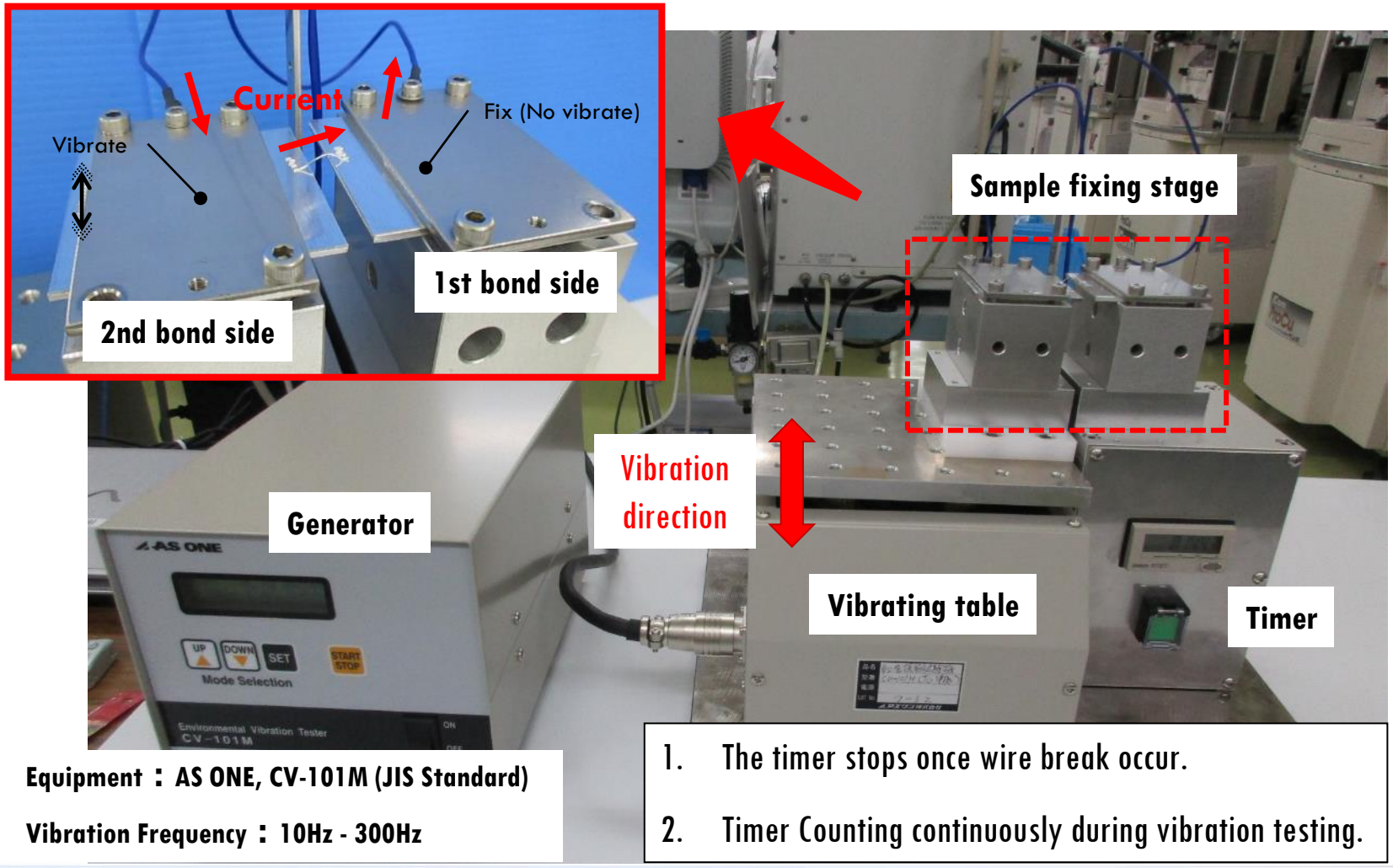
1. Introduction of vibration tests equipment developed for this study

2. 5 kinds of comparison study results (Material, Ribbon or Loop height)





Vibration test equipment



Test Equipment were placed in the clean room.

Room temperature (around 20oC)

Humidity : around 50%RH

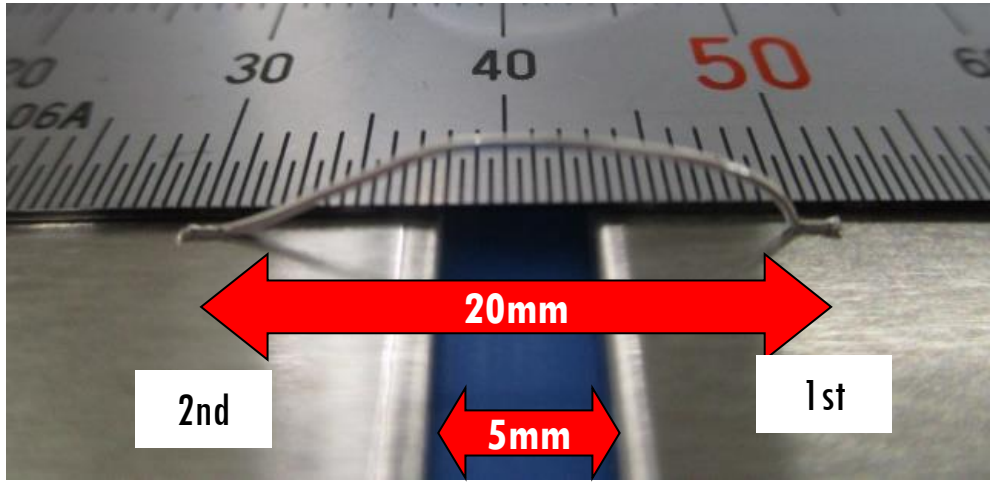
Equipment : AS ONE, CV-101M (JIS Standard)

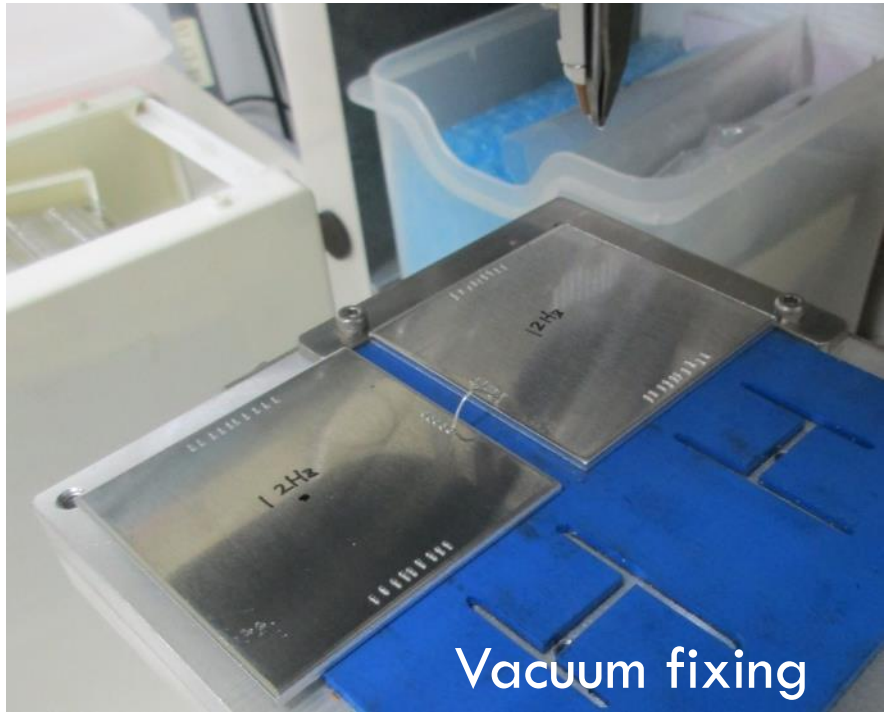
Vibration Frequency : 10Hz - 300Hz

1. The timer stops once wire break occur.
2. Timer Counting continuously during vibration testing.

Sample preparation (Bonding)

Bonder	Asterion
Wedge tool	127591-16A
US-Power	80
Force [gf]	500 / 900
Time [ms]	50 / 150
Substrate	Al Plate (50×50×2 mmt)





Bonding wire
between 2 plates

Vibration Test condition (Frequency Hz / Acceleration G)

Vibration test were conducted under various amplitude conditions by changing Frequency Hz

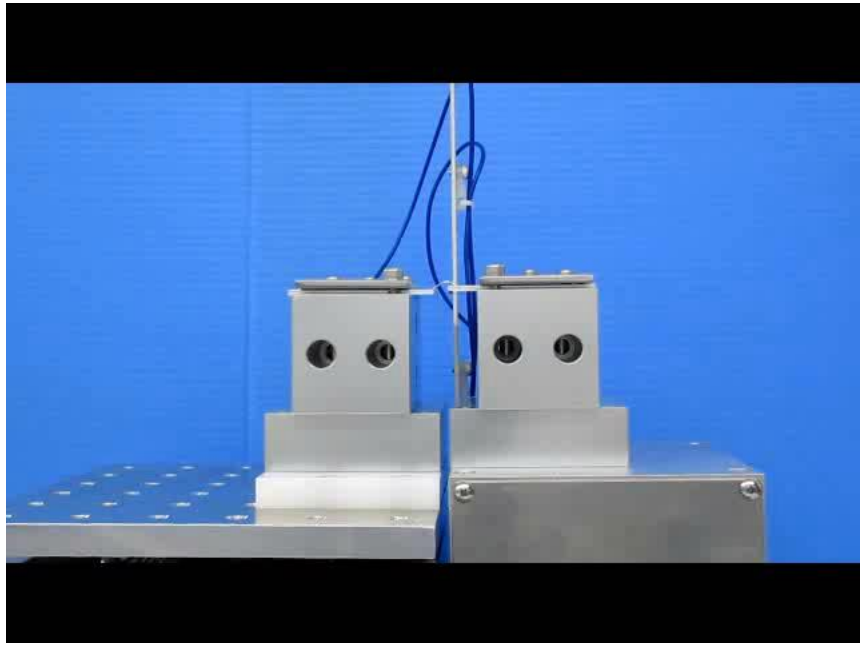
Frequency	Acceleration	Amplitude
[Hz]	[m/s^2]	[mm]
10	1.0G	2.484
12		1.725
21		0.563
25		0.397
50		0.099
70		0.051

Calculation formula of 'Amplitude' from 'Frequency' and 'Acceleration'

$$A=(2\pi f)^2\times D/1000 \quad (m/s^2)$$

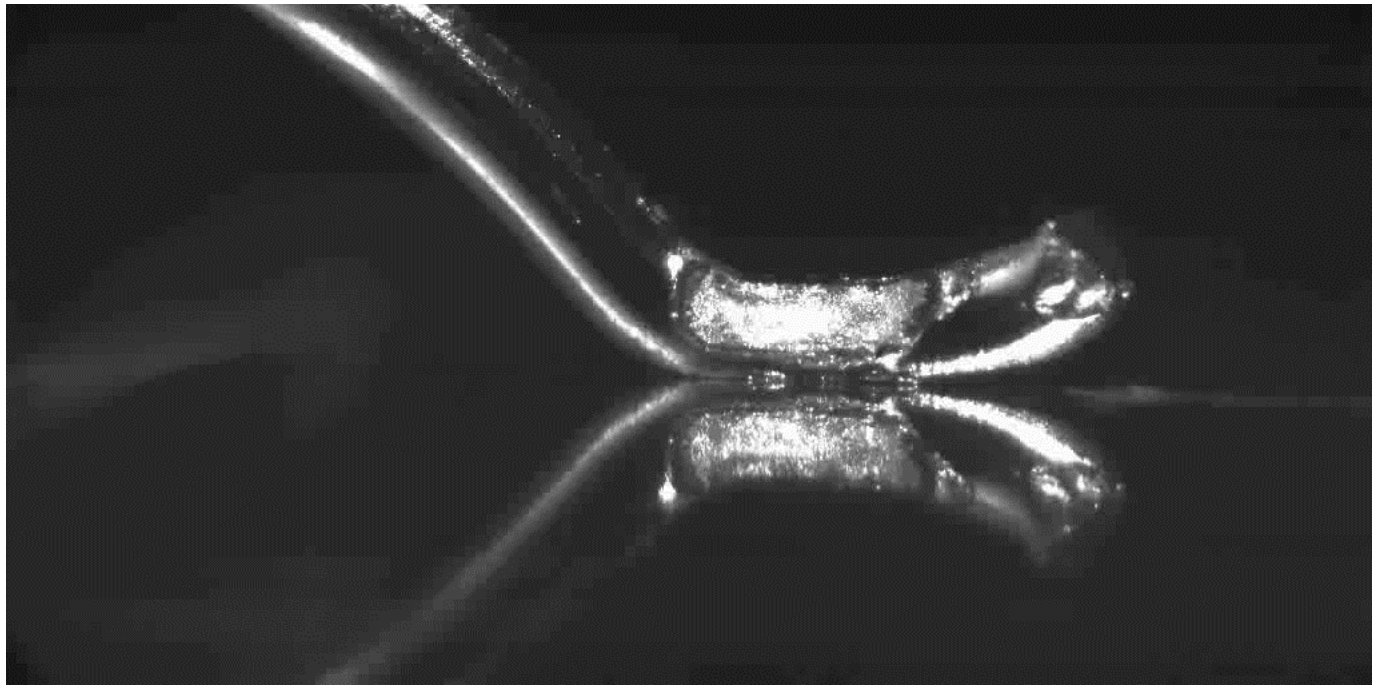
A : Acceleration(m/s^2) D : Amplitude(mm) f : Frequency(Hz)

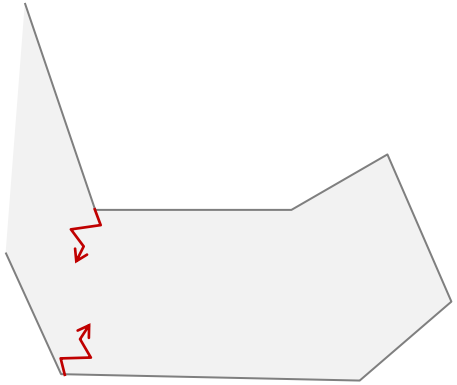
Movie : Vibration test



Wire break after 28 seconds vibration... (Timer stop due to wire break)

Movie : High Speed camera, wire break at neck





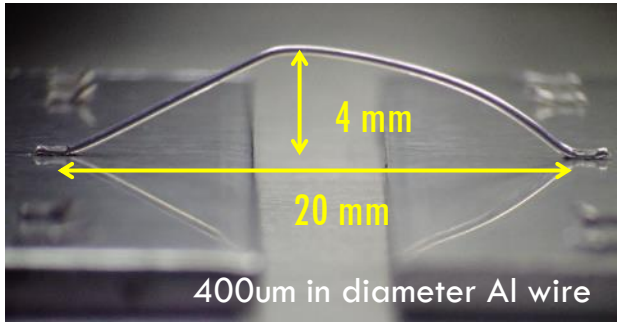
Crack propagate with vibrated

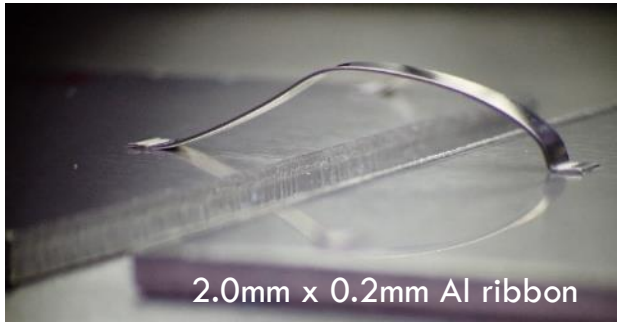
Test Matrix

5 kinds of comparison tests were completed

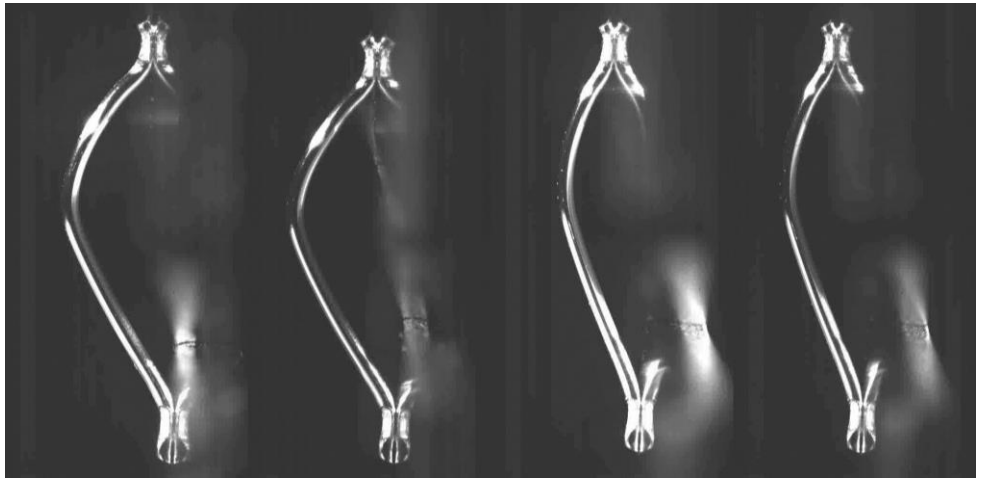
Test No	Factor	Comparison
1	Vibrate Direction (x, y, z)	3 direction (x, y and z)
2	Wire Materials	4 different Al alloy wire
3	Loop Height	Low, Middle and High loop height
4	Ribbon shape	Wire shape vs Ribbon shape
5	Fixing	One side vibrated vs Both side

Wire diameter : 400um
Ribbon size : w2.0 x t0.2mm
Loop length : 20mm
Loop height : 4mm

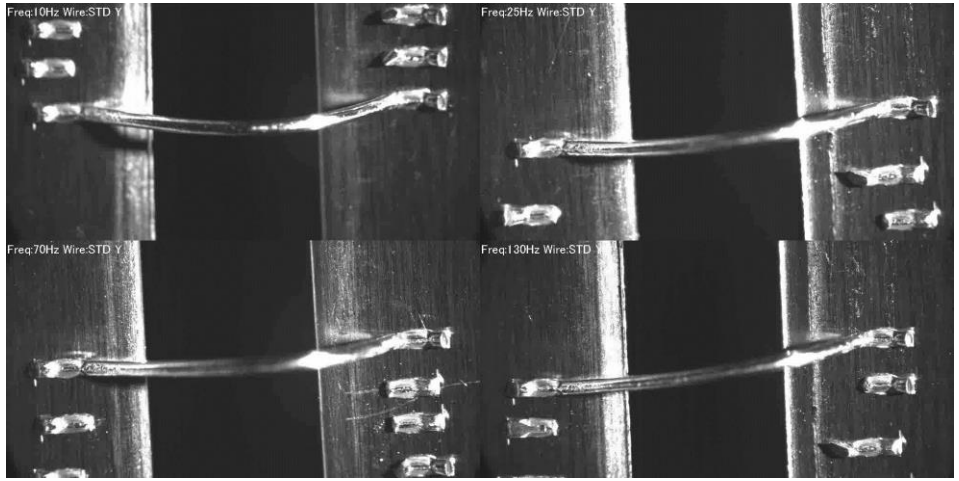




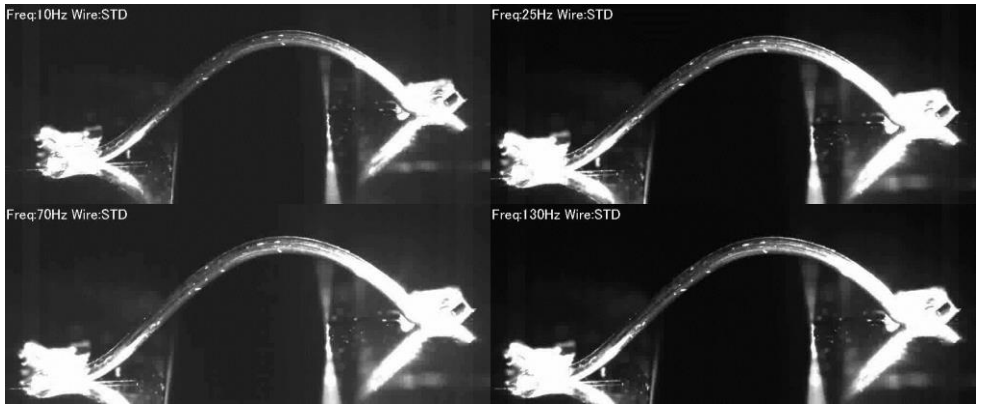
Test-1 : Direction (High Speed camera, x / y / z direction)



X direction

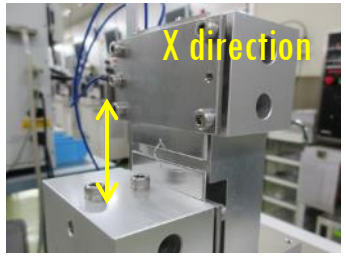


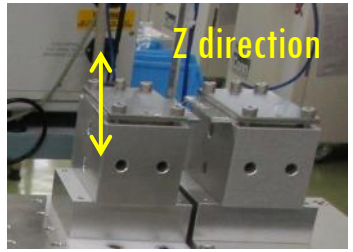
Y direction

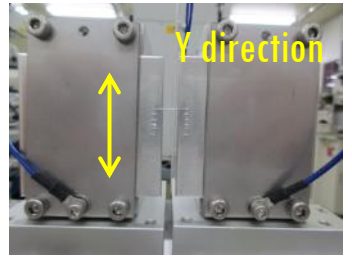


Z direction

3 different vibrate direction (X, Y, Z) was compared

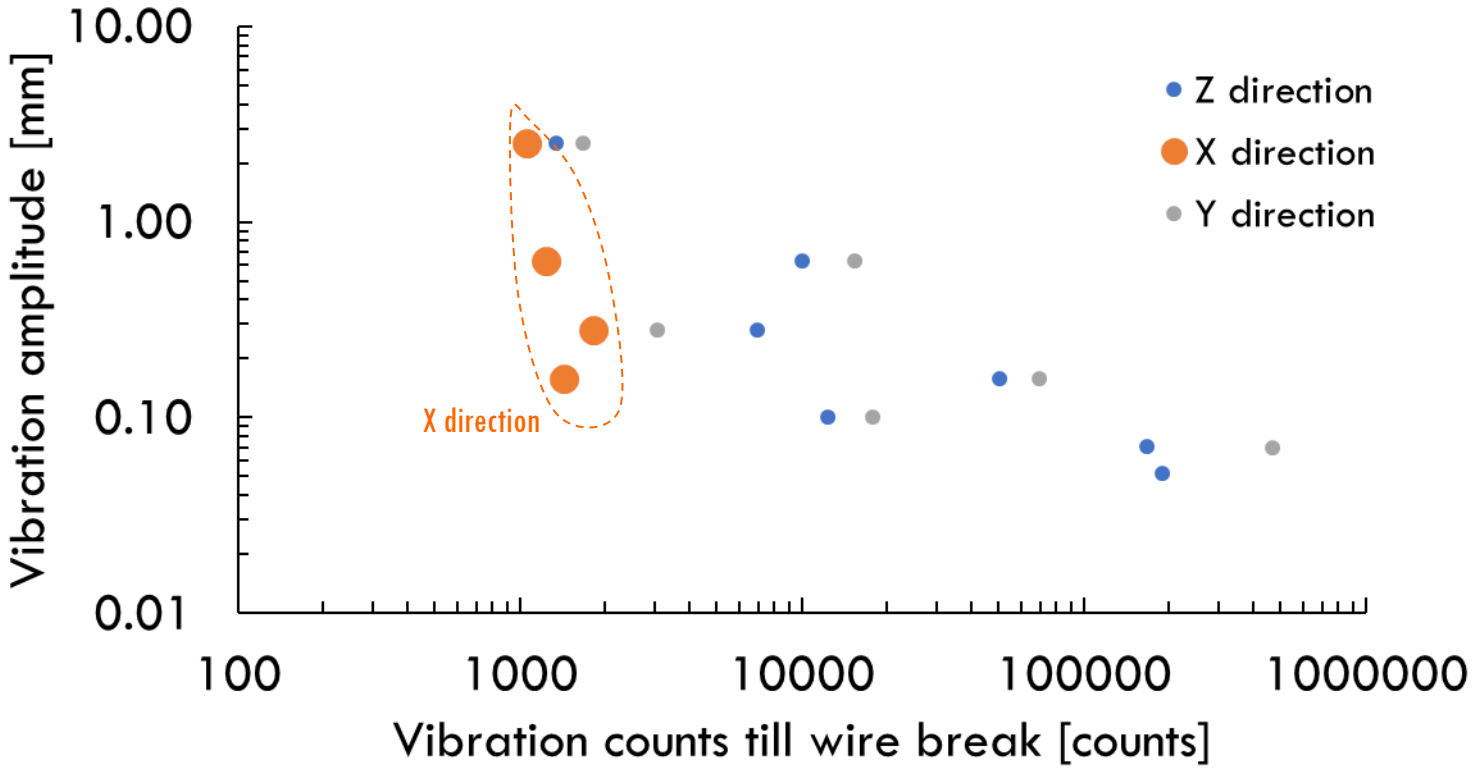


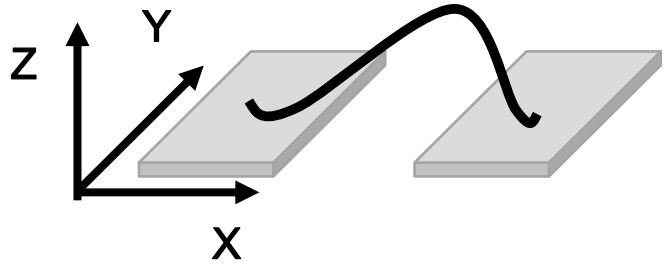




Note : This movie were taken with loop length, 10mm samples

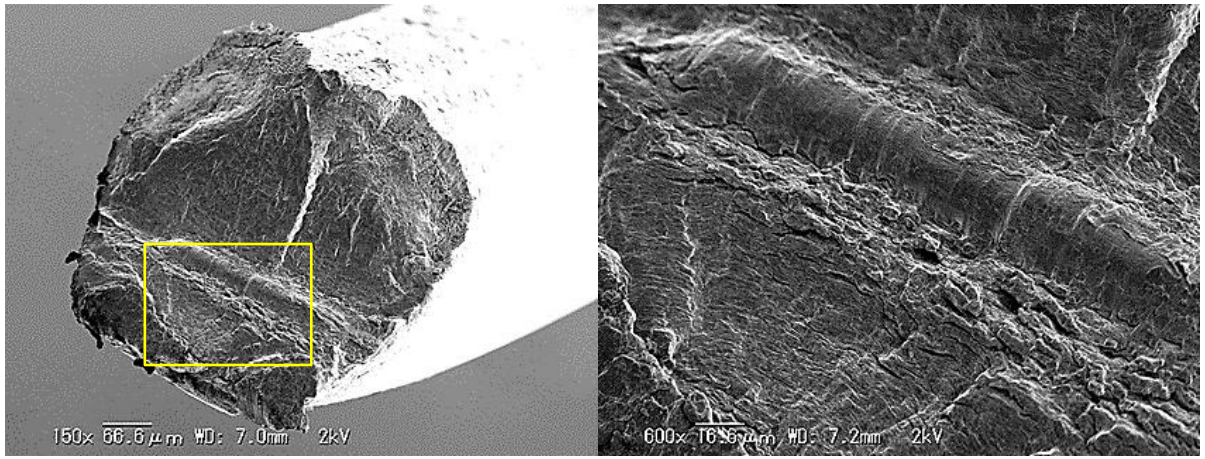
Test-1 : Vibrate Direction



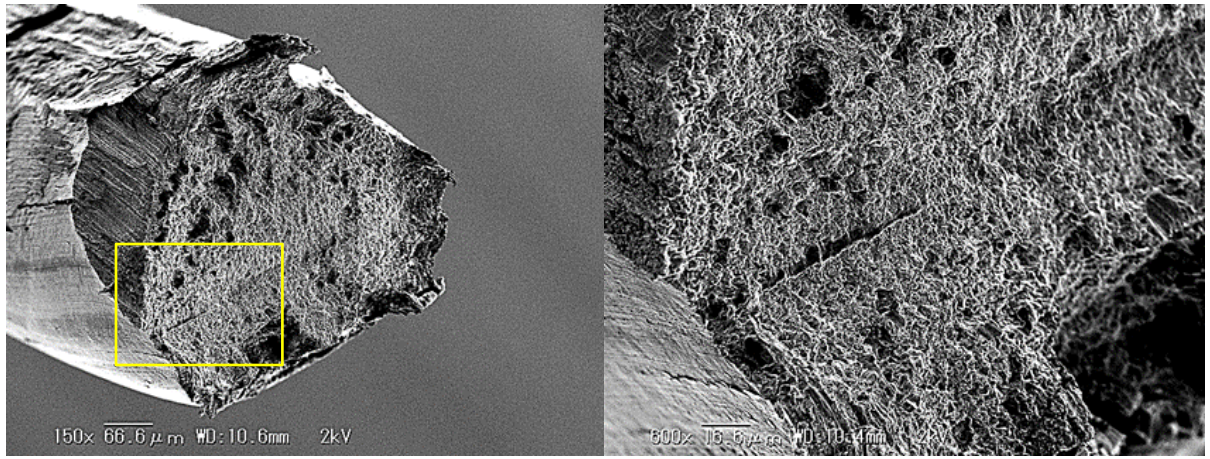


Fastest wire break were seen X direction under same amplitude compare to y and z direction.

SEM Photo (Z direction)

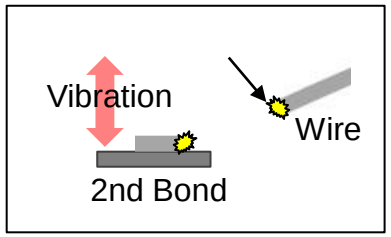


Low magnification　　High magnification

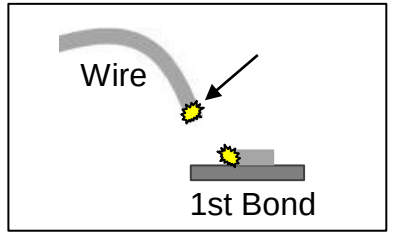


Low magnification　　High magnification

Large amplitude (2.5mm)



Small amplitude (0.05mm)

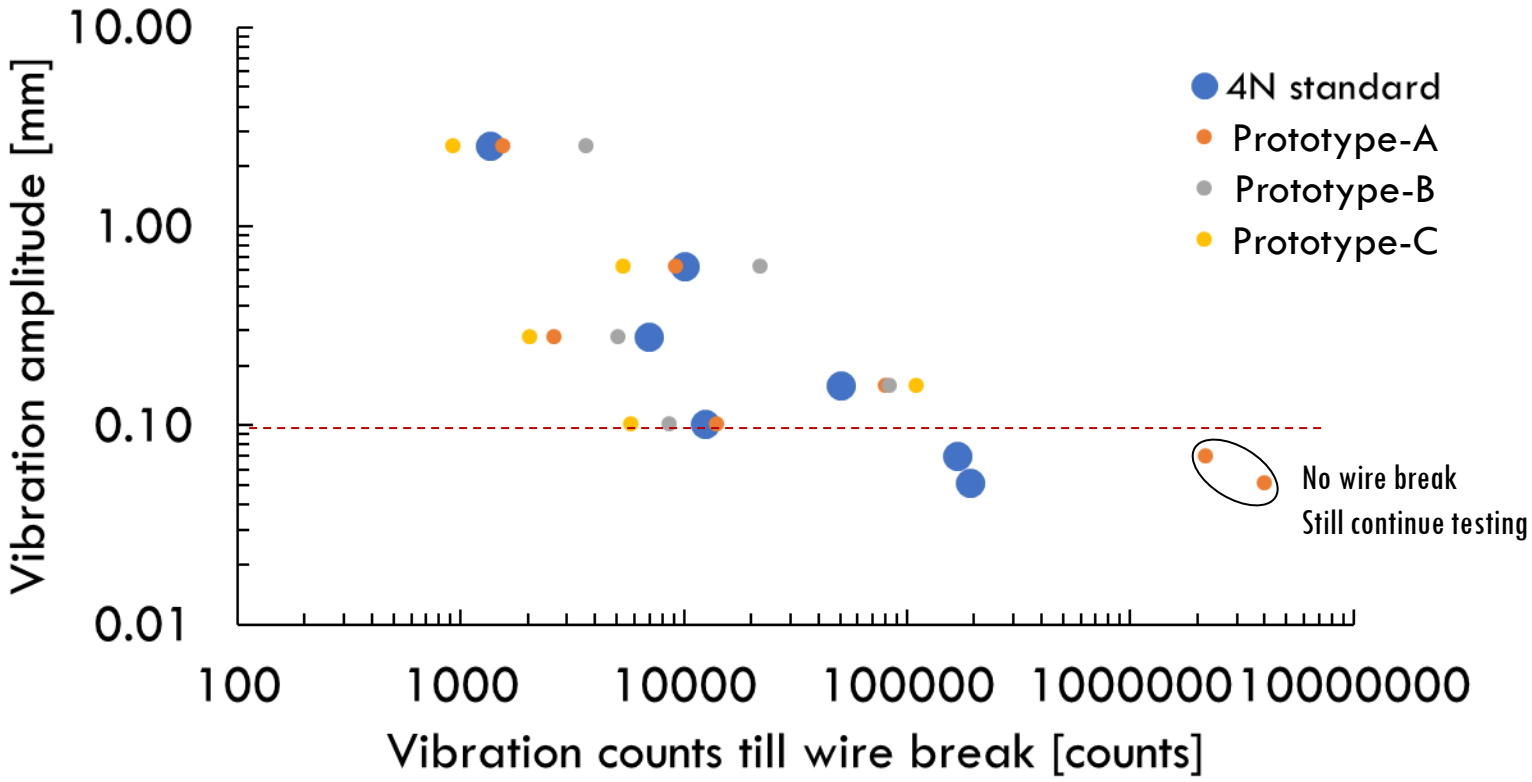


Test-2 : Wire Materials (Wire properties)

In order to study any possibility of vibration resistance improvement compare to standard 4N wire, 3 kinds of Al alloy were subjected to test

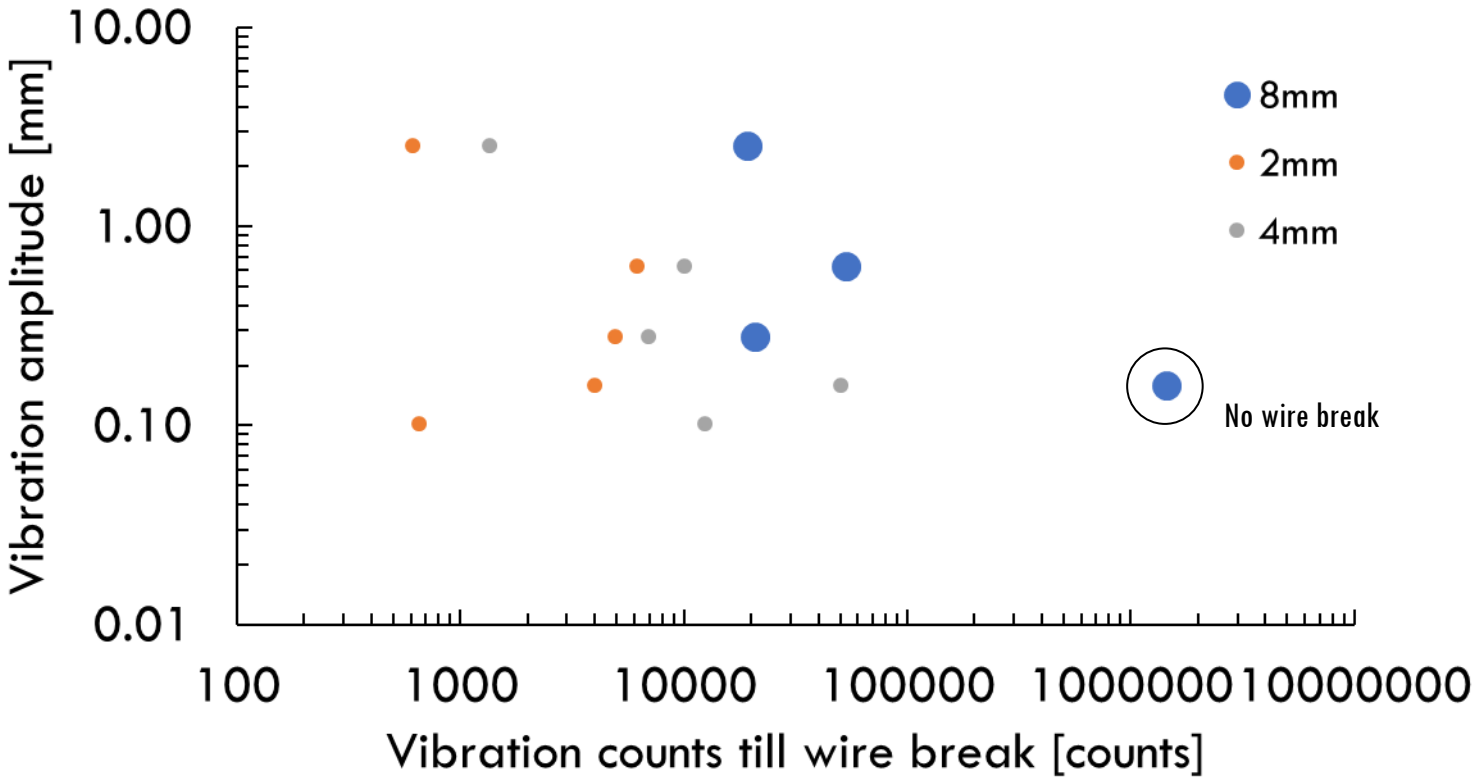
No	Wire	Tensile Strength (MPa)	Electrical Conductivity (%IACS)
1	4N (99.99%) standard	50	63
2	Al alloy prototype-A	140	55
3	Al alloy prototype-B	130	50
4	Al alloy prototype-C	130	59

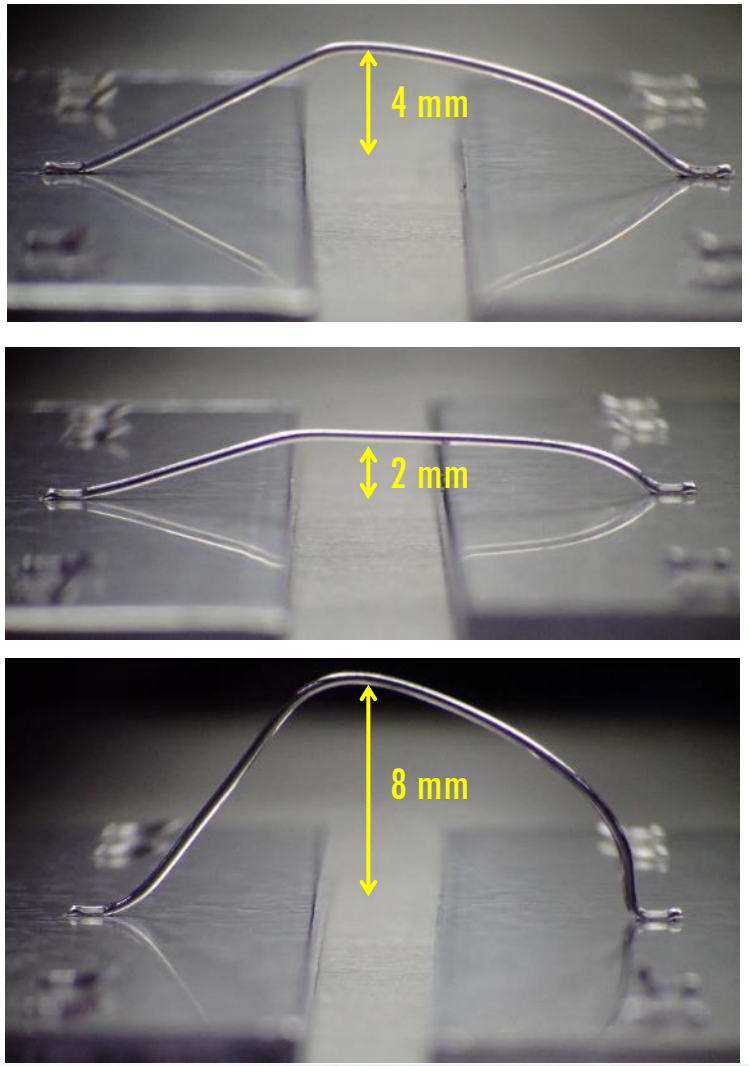
Test-2 : Wire Materials (Vibration test results, Z direction only)



High strength wire by alloying were seems not to be so effective for improve vibration resistance under amplitude >0.1mm. However, if the amplitude <0.1mm, high strength wire showed much improve vibration resistance compare to 4N wire.

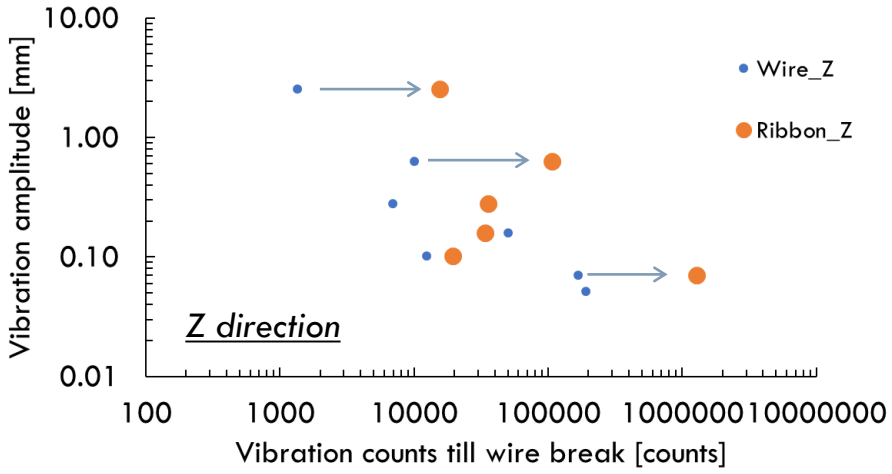
Test-3 : Loop Height (Z direction only)

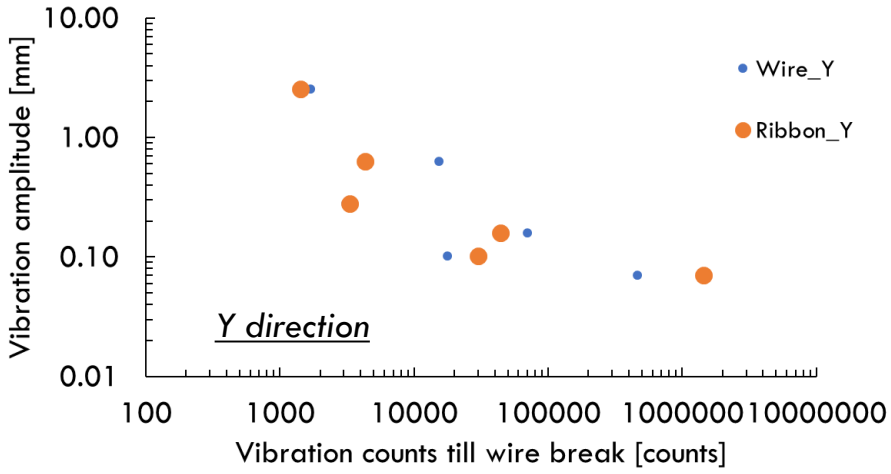


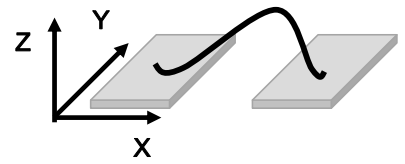


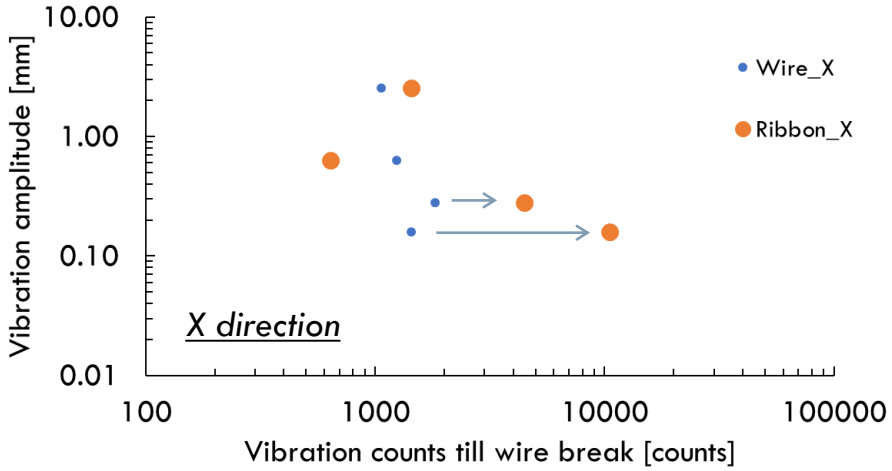
Higher loop height showed much improvement of vibration resistance.

Test-4 : Wire vs Ribbon









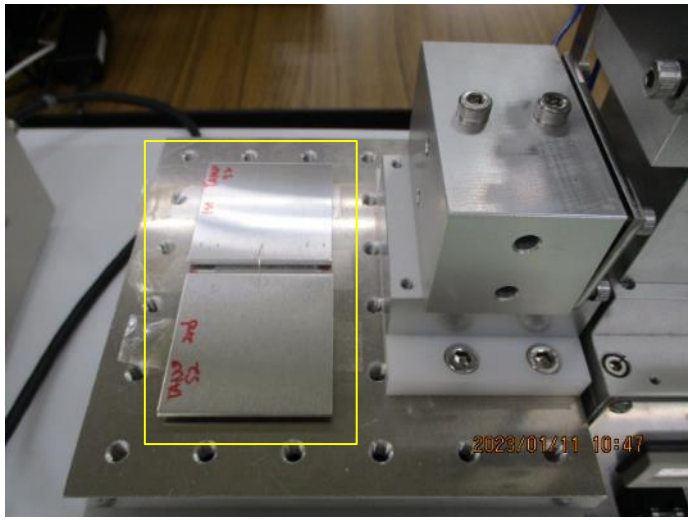
Z and X direction

Ribbon shape showed better resistance than wire.

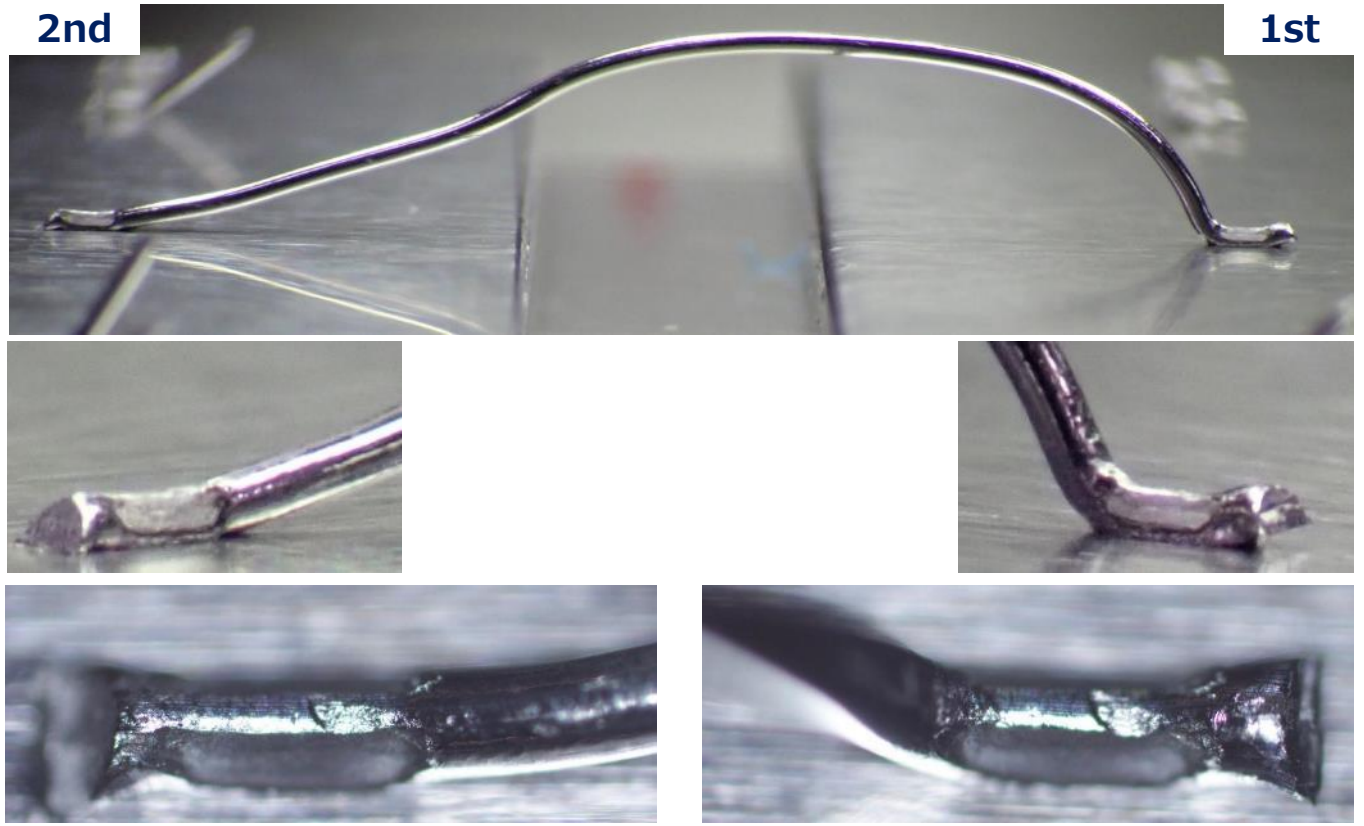
Y direction

Wire shape showed better resistance than ribbon.

Test-5 : Vibrate both side (1st bond , 2nd bond)



Both substrate were placed on vibration generator



No wire break was observed even applied longer vibration if both substrate placed on vibration generator.

Summary

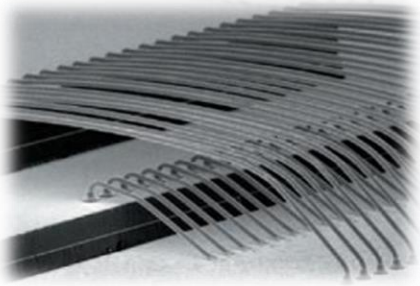
- Fixing cylinder cell and busbar is important for resistance of vibration
- Recommend higher loop height setting because of absorption of vibration
- Higher strength wire showed higher resistance of vibration only the condition of amplitude less than 0.1mm
- Ribbon shape showed better resistance than wire under specific vibration direction

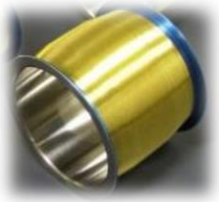
TANAKA Bonding wire

Au

【IC・Memory】

- ATV・High reliability
- Fine pitch device

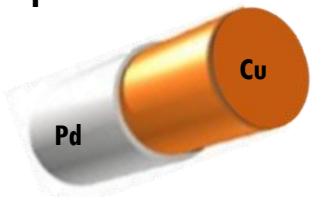




Cu

【IC】

- ATV・High reliability
- Fine pitch device



【Power】

- Low resistivity
- Bond-ability

Ag

【Memory・LED】

- Low resistivity
- High reliability

Al

【Power】

- High reliability
- Bond-ability

Please feel free to contact us if you want to try with any bonding materials, we can provide various materials.