Lab 1: Ultrasonic Metal Welding

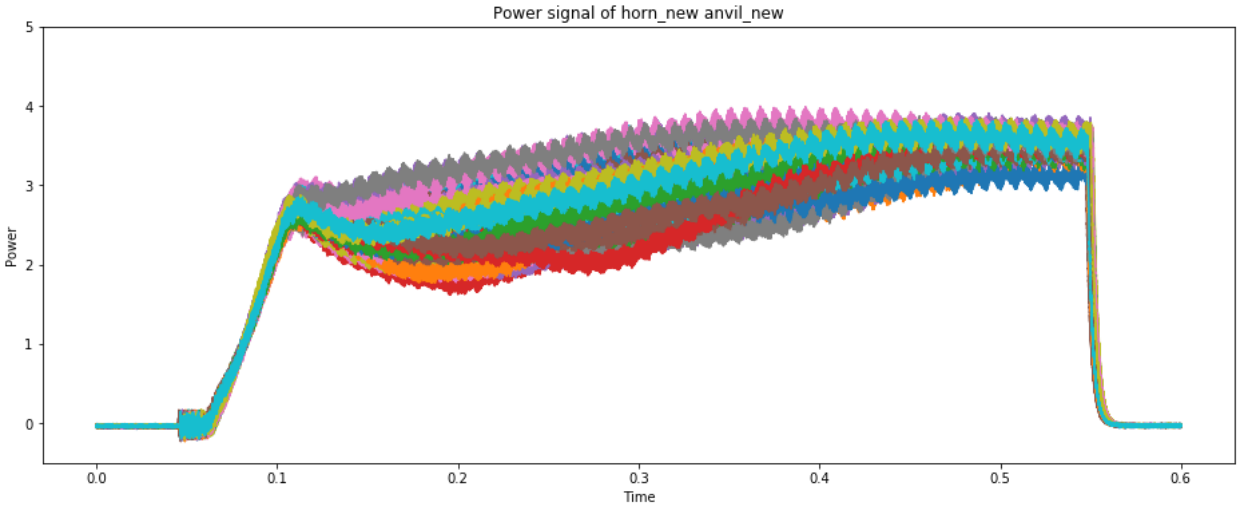
ME498: Group 2

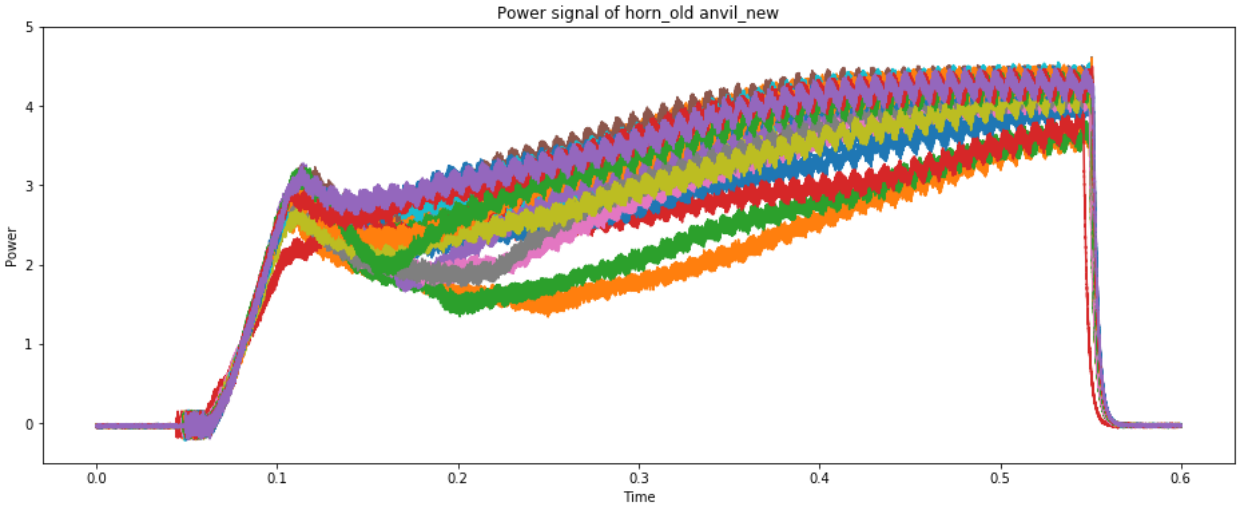
4 Credit Hours: Zhiqiao Dong, Yulun Wu

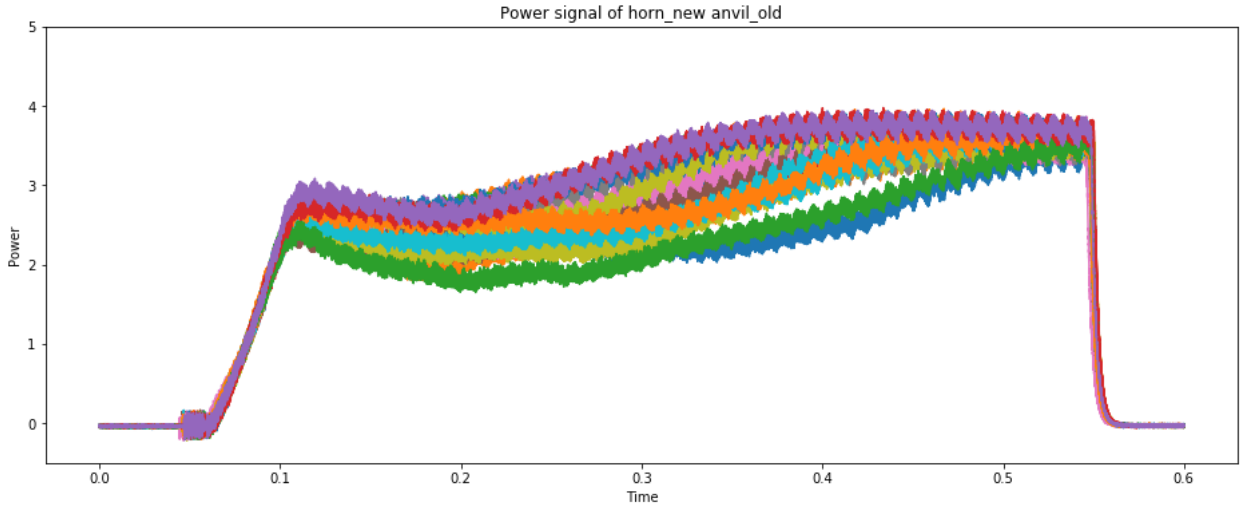
3 Credit Hours: Evan Cali, Megan Voris, Allen Ho

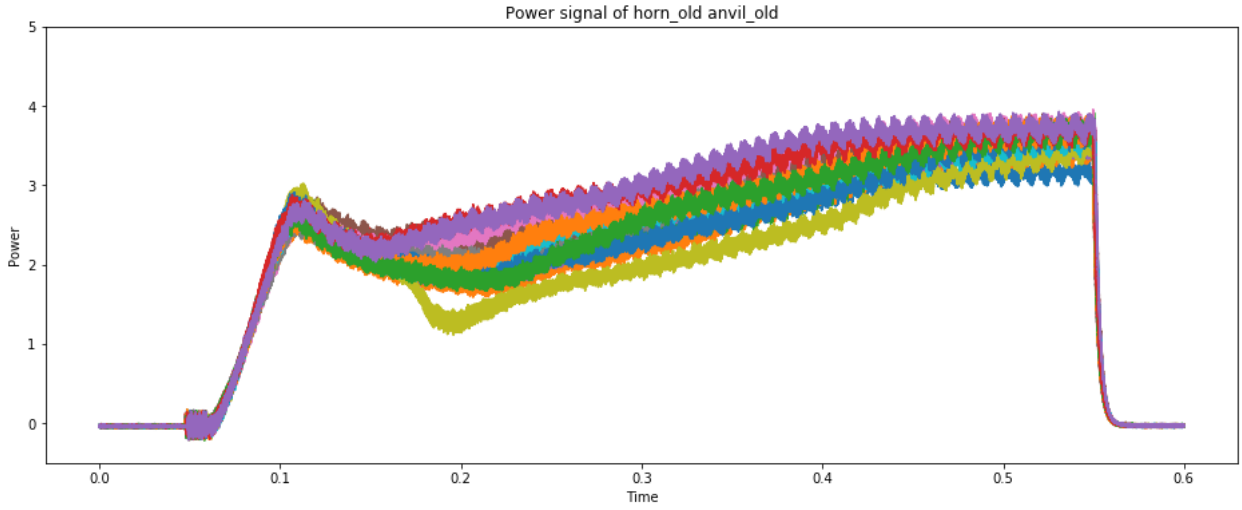
(1) Influence of tool conditions.

i. level 0 samples, 4 tool conditions.







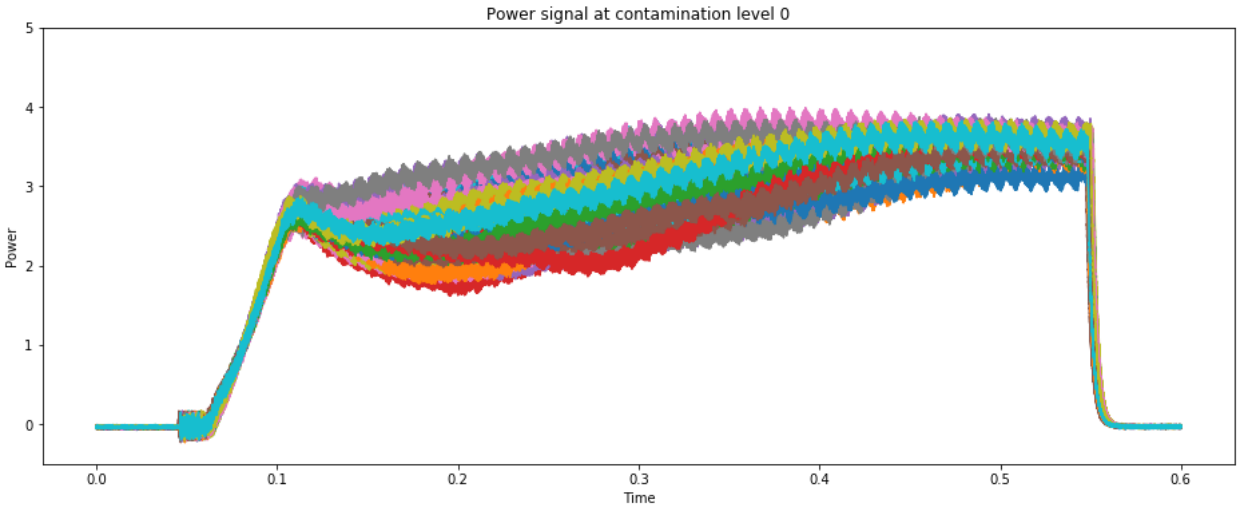


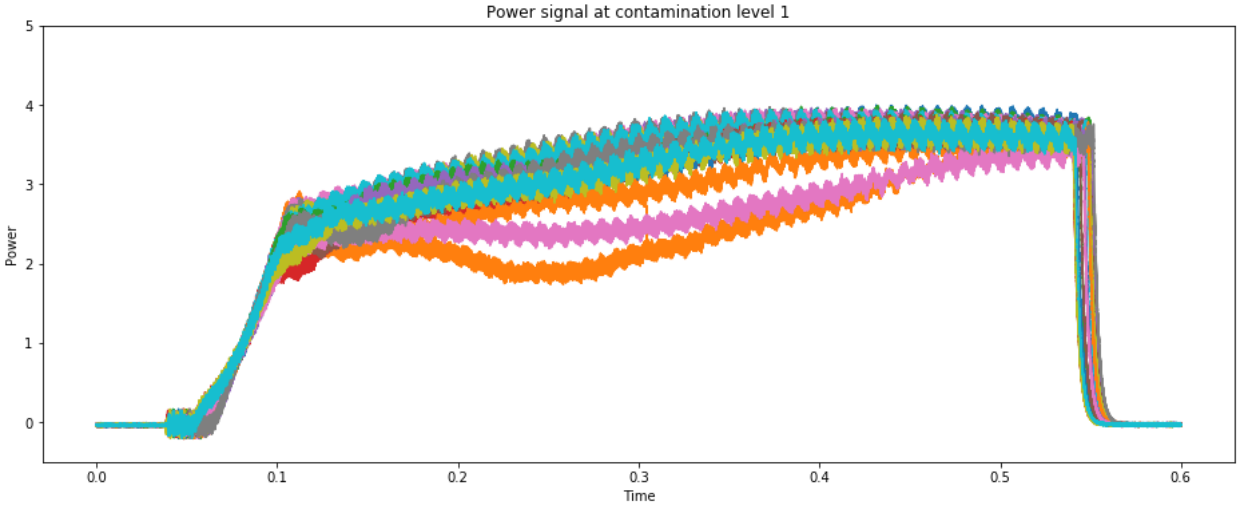
ii. What differences can you tell from the plots? No quantitative measures are needed.

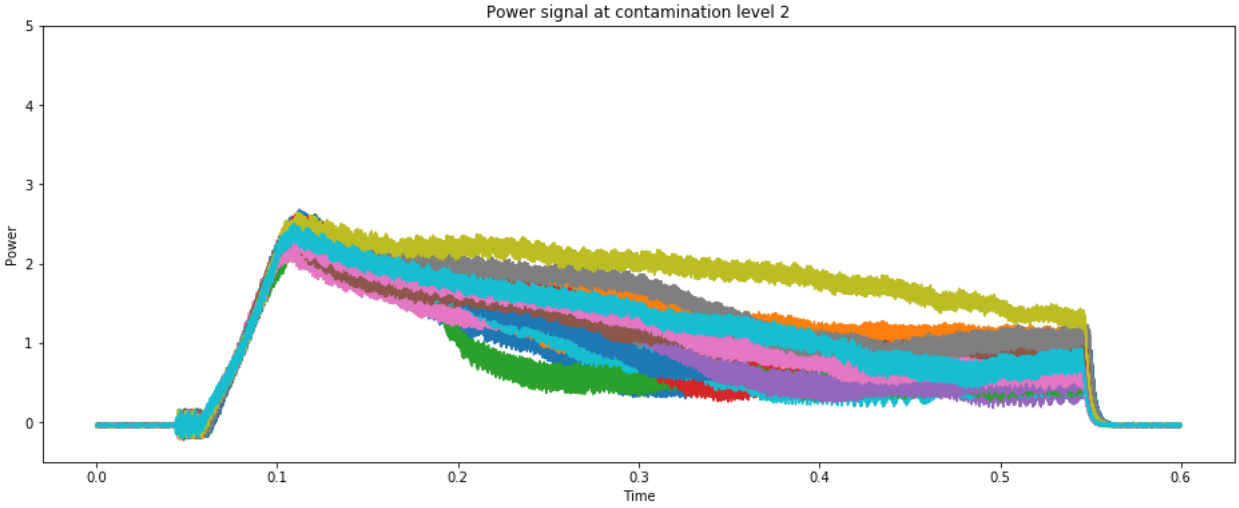
When referencing the power signal of the various equipment combinations tested, it appears that the power fluctuates (difference between the lowest power level and highest power level during welding phase) the least when the ultrasonic welding system is equipped with a new horn and new anvil. In terms of the anvil alone, it appears that when welding with an older one the power signals vary less. This could be a result of the more uniform surface roughness that comes from the wear its age implies. When further observing the influence of the anvil, it appears that the peak power signal of samples with old anvil's is lower than the samples welded with new anvils. On the other hand, something worth noting is that it appears that the decrease in power measured after the initial linear increase is greater in magnitude in samples welded with an old horn. Additionally, when comparing the 4 conditions there appears to be, at least in part, a correlation between old horn's and higher power values. Lastly, the combination of old horn's and new anvil's lead to the dataset with the highest degree of variance.

(2) Influence of surface contamination.

i. new tools, 3 contamination levels







ii. What differences can you tell from the plots? No quantitative measures are needed.

From the three plots that compare the power signals at three different contamination levels, it can be seen that the power signals remain the same between contamination levels zero and one. However, the power signal is greatly decreased with contamination level two, decreasing significantly, especially at the end of the welding process. A difference between contamination level zero and level one is that at contamination level one, the power signals vary less in between different specimens being welded, and thus the variance is lower. Also, for contamination level zero, it appears that the power level decreases slightly right after the beginning of the weld. It is interesting to note that both level zero and level one contamination levels cause power to increase over the time of the weld; however, a decreasing trend in power can be observed when looking at the contamination level two graph.

Contamination level 2 is significantly reducing the power signal.
Contamination level 1 maintain the similar power signal shape compared to Contamination level 0 while with a little more concentration.

(3) Frequency analysis.

i. Perform Fast Fourier Transform (FFT) for all AE and microphone signals.
ii. Record the peak frequency around 20 kHz (f) and the corresponding power value (P).

AE:

Group1 horn_old anvil_newlevel 0 F:19895.00 P:0.0176 F:19885.00 P:0.0412 F:19885.00 P:0.0465 F:19805.00 P:0.0473 F:1989P:0.00 P:0.0138 F:19888.33 P:0.0214 F:19895.00 P:0.0279 F:19883.33 P:0.0259 F:19890.00 P:0.0239 F:19893.33 P:0.0248 F:19803.33 P:0.0252 F:19891.67 P:0.0256 F:19890.00 P:0.0335 F:1989P:0.00 P:0.0282 F:19886.67 P:0.0294 F:19891.67 P:0.0261 F:19893.33 P:0.0286 F:19886.67 P:0.0238 F:19895.00 P:0.0369 F:1989P:0.00 P:0.0267 F:19891.67 P:0.0274 F:19890.00 P:0.0340 F:19886.67 P:0.0256 F:19885.00 P:0.0233 F:19885.00 P:0.0267

Group1 horn_old anvil_newlevel 1 F:1988P:0.00 P:0.0521 F:19883.33 P:0.0427 F:19885.00 P:0.0461 F:1988P:0.00 P:0.0468 F:1988P:0.00 P:0.0537 F:19881.67 P:0.0550 F:1988P:0.00 P:0.0443 F:19886.67 P:0.0274 F:19881.67 P:0.0582 F:19881.67 P:0.0501

Group1 horn_old anvil_newlevel 2 F:1989P:0.00 P:0.0690 F:19880.00 P:0.0654 F:19828.33 P:0.0557 F:19816.67 P:0.0732 F:19823.33 P:0.0652 F:19818.33 P:0.0576 F:19828.33 P:0.0738 F:19821.67 P:0.0654 F:19810,00 P:0.0565 F:19820,00 P:0.0795

Group2 horn_new anvil_oldlevel 0 F:19803.33 P:0.0289 F:19898.33 P:0.0334 F:20018.33 P:0.0299 F:19800,00 P:0.0315 F:19800,00 P:0.0362 F:19801.67 P:0.0243 F:19803.33 P:0.0193 F:19898.33 P:0.0261 F:19801.67 P:0.0338 F:19896.67 P:0.0275 F:19803.33 P:0.0306 F:19896.67 P:0.0214 F:19801.67 P:0.0362 F:19803.33 P:0.0288 F:19801.67

P:0.0298 F:19898.33 P:0.0284 F:19803.33 P:0.0314 F:19896.67 P:0.0292 F:19800,00
P:0.0289 F:19898.33 P:0.0315 F:19895.00 P:0.0308 F:19898.33 P:0.0308 F:19891.67
P:0.0316 F:19886.67 P:0.0263 F:19886.67 P:0.0305

Group2 horn_old anvil_newlevel 1 F:19886.67 P:0.0244 F:19888.33 P:0.0258 F:19885.00
P:0.0188 F:19888.33 P:0.0282 F:19886.67 P:0.0252 F:19886.67 P:0.0235 F:19888.33
P:0.0316 F:19886.67 P:0.0301 F:19888.33 P:0.0284 F:1989P:0.00 P:0.0316

Group2 horn_old anvil_newlevel 2 F:19888.33 P:0.0338 F:19818.33 P:0.0320 F:19833.33
P:0.0371 F:19823.33 P:0.0359 F:19888.33 P:0.0322 F:19818.33 P:0.0376 F:19813.33
P:0.0406 F:19816.67 P:0.0331 F:19811.67 P:0.0308 F:19811.67 P:0.0322

Group3 horn_new anvil_newlevel 0 F:19898.33 P:0.0187 F:19818.33 P:0.0161 F:19816.67
P:0.0202 F:19816.67 P:0.0250 F:19816.67 P:0.0265 F:19818.33 P:0.0262 F:19828.33
P:0.0249 F:19815.00 P:0.0295 F:19838.33 P:0.0193 F:19885.00 P:0.0157 F:19815.00
P:0.0255 F:19811.67 P:0.0175 F:19816.67 P:0.0310 F:19890.00 P:0.0220 F:19815.00
P:0.0242 F:19881.67 P:0.0181 F:19811.67 P:0.0215 F:19830,00 P:0.0224 F:19835.00
P:0.0158 F:19835.00 P:0.0153

Group3 horn_new anvil_newlevel 1 F:19810,00 P:0.0294 F:19810,00 P:0.0316 F:19813.33
P:0.0211 F:19808.33 P:0.0197 F:19810,00 P:0.0150 F:19811.67 P:0.0247 F:19810,00
P:0.0186 F:19813.33 P:0.0159 F:19810,00 P:0.0139 F:19808.33 P:0.0276

Group3 horn_new anvil_newlevel 2 F:19806.67 P:0.0421 F:19806.67 P:0.0412 F:19893.33
P:0.0324 F:19806.67 P:0.0405 F:19895.00 P:0.0491 F:19893.33 P:0.0323 F:19895.00
P:0.0428 F:19806.67 P:0.0406 F:19800,00 P:0.0454 F:19806.67 P:0.0389

Group4 horn_new anvil_newlevel 0 F:19896.67 P:0.0317 F:19830,00 P:0.0272 F:19821.67
P:0.0255 F:19820,00 P:0.0 F:198 F:19833.33 P:0.0159 F:19816.67 P:0.0177 F:19826.67
P:0.0168 F:19823.33 P:0.0190 F:19821.67 P:0.0185 F:19823.33 P:0.0139 F:19840,00
P:0.0158 F:19801.67 P:0.0131 F:19823.33 P:0.0137 F:19830,00 P:0.0161 F:19835.00
P:0.0173 F:19801.67 P:0.0190 F:19825.00 P:0.0148 F:19843.33 P:0.0130 F:19830,00
P:0.0113 F:19831.67 P:0.0152

Group4 horn_old anvil_newlevel 1 F:19831.67 P:0.0104 F:19871.67 P:0.0143 F:19831.67
P:0.0200 F:19848.33 P:0.0131 F:19813.33 P:0.0185 F:20083.33 P:0.0209 F:19835.00
P:0.0202 F:19830,00 P:0.0215 F:19896.67 P:0.0436 F:19896.67 P:0.0515 F:19801.67
P:0.0385 F:19835.00 P:0.0369 F:19803.33 P:0.0484 F:19800,00 P:0.0410 F:19896.67
P:0.0451 F:19800,00 P:0.0438 F:19800,00 P:0.0503 F:19800,00 P:0.0362 F:19801.67
P:0.0369 F:19898.33 P:0.0384

Group5 horn_old anvil_oldlevel 0 F:19803.33 P:0.0390 F:19800,00 P:0.0353 F:19800,00
P:0.0381 F:19801.67 P:0.0362 F:19801.67 P:0.0353 F:19803.33 P:0.0307 F:19898.33

P:0.0375 F:19800,00 P:0.0276 F:19810,00 P:0.0325 F:19808.33 P:0.0255 F:19806.67 P:0.0280 F:19806.67 P:0.0337 F:19808.33 P:0.0316 F:19898.33 P:0.0288 F:19898.33 P:0.0266 F:19801.67 P:0.0298 F:19808.33 P:0.0264 F:20020,00 P:0.0267 F:19806.67 P:0.0297 F:19806.67 P:0.0326 F:19801.67 P:0.0288 F:19881.67 P:0.0255 F:19888.33 P:0.0370 F:19878.33 P:0.0236 F:20023.33 P:0.0249

Group5 horn_old anvil_oldlevel 1

F:19878.33 P:0.0349 F:19878.33 P:0.0389 F:19878.33 P:0.0273 F:19880.00 P:0.0374 F:19878.33 P:0.0423 F:19878.33 P:0.0347 F:19873.33 P:0.0542 F:19878.33 P:0.0550 F:19878.33 P:0.0461

Group5 horn_old anvil_oldlevel 2

F:19808.33 P:0.0672 F:19813.33 P:0.0671 F:19815.00 P:0.0568 F:19803.33 P:0.0557 F:19816.67 P:0.0505 F:19820,00 P:0.0494 F:19806.67 P:0.0519 F:19898.33 P:0.0651 F:19876.67 P:0.0412 F:19876.67 P:0.0411

Microphone

Group1 horn_old anvil_newlevel 0 F:19900.00 Hz P:0.0659 F:19893.33 Hz P:0.1233 F:19890.00 Hz P:0.0957 F:19900.00 Hz P:0.1401 F:19898.33 Hz P:0.0901 F:19901.67 Hz P:0.1139 F:19898.33 Hz P:0.0794 F:19896.67 Hz P:0.1235 F:20070.00 Hz P:0.0617 F:19900.00 Hz P:0.0982 F:19898.33 Hz P:0.0802 F:19898.33 Hz P:0.0900 F:19896.67 Hz P:0.1306 F:19896.67 Hz P:0.1109 F:19901.67 Hz P:0.0990 F:19900.00 Hz P:0.0908 F:19896.67 Hz P:0.1175 F:19898.33 Hz P:0.1069 F:19905.00 Hz P:0.1503 F:19900.00 Hz P:0.0968 F:19896.67 Hz P:0.1094 F:19893.33 Hz P:0.1423 F:19888.33 Hz P:0.0825 F:19893.33 Hz P:0.1151 F:19891.67 Hz P:0.1077

Group1 horn_old anvil_newlevel 1 F:19885.00 Hz P:0.1135 F:19888.33 Hz P:0.0953 F:19886.67 Hz P:0.1038 F:19883.33 Hz P:0.0720 F:19885.00 Hz P:0.1128 F:19886.67 Hz P:0.0860 F:19881.67 Hz P:0.0809 F:19890.00 Hz P:0.0795 F:19883.33 Hz P:0.0979 F:19883.33 Hz P:0.0822

Group1 horn_old anvil_newlevel 2 F:19923.33 Hz P:0.1853 F:19920.00 Hz P:0.1979 F:19928.33 Hz P:0.2039 F:19928.33 Hz P:0.1717 F:19931.67 Hz P:0.1453 F:19930.00 Hz P:0.1817 F:19926.67 Hz P:0.1938 F:19928.33 Hz P:0.1742 F:19931.67 Hz P:0.1837 F:19881.67 Hz P:0.1674

Group2 horn_new anvil_oldlevel 0 F:20023.33 Hz P:0.0798 F:19921.67 Hz P:0.0757 F:19903.33 Hz P:0.0973 F:19988.33 Hz P:0.0652 F:19958.33 Hz P:0.1191 F:19995.00 Hz P:0.0533 F:19903.33 Hz P:0.0774 F:20001.67 Hz P:0.0604 F:19915.00 Hz P:0.0885 F:20020.00 Hz P:0.0600 F:19901.67 Hz P:0.0521 F:20025.00 Hz P:0.0473 F:19973.33 Hz P:0.0671 F:19991.67 Hz P:0.0499 F:19916.67 Hz P:0.0565 F:20025.00 Hz P:0.0777 F:20045.00 Hz P:0.0628 F:19910.00 Hz P:0.0617 F:19913.33

Hz P:0.0766 F:19965.00 Hz P:0.0760 F:20030.00 Hz P:0.0578 F:20026.67 Hz P:0.0634 F:19965.00 Hz P:0.0922 F:19981.67 Hz P:0.0631 F:20018.33 Hz P:0.0618

Group2 horn_new anvil_oldlevel 1 F:19961.67 Hz P:0.0653 F:20008.33 Hz P:0.0786 F:19891.67 Hz P:0.0701 F:19998.33 Hz P:0.0833 F:20011.67 Hz P:0.0778 F:20015.00 Hz P:0.0705 F:19905.00 Hz P:0.0892 F:20030.00 Hz P:0.0733 F:20026.67 Hz P:0.0644 F:20021.67 Hz P:0.0611

Group2 horn_new anvil_oldlevel 2 F:19936.67 Hz P:0.1378 F:19913.33 Hz P:0.1110 F:19931.67 Hz P:0.0646 F:19905.00 Hz P:0.0475 F:19890.00 Hz P:0.0671 F:19933.33 Hz P:0.0935 F:19933.33 Hz P:0.1092 F:19888.33 Hz P:0.0462 F:19931.67 Hz P:0.1079 F:19930.00 Hz P:0.0808

Group3 horn_new anvil_newlevel 0 F:19910.00 Hz P:0.0650 F:19931.67 Hz P:0.1055 F:19906.67 Hz P:0.0630 F:19915.00 Hz P:0.1002 F:19926.67 Hz P:0.0613 F:20070.00 Hz P:0.0485 F:19936.67 Hz P:0.0810 F:19903.33 Hz P:0.0361 F:19918.33 Hz P:0.0751 F:20130.00 Hz P:0.0671 F:19921.67 Hz P:0.1140 F:19905.00 Hz P:0.0566 F:19926.67 Hz P:0.0555 F:19916.67 Hz P:0.1265 F:19921.67 Hz P:0.0983 F:20101.67 Hz P:0.0547 F:19913.33 Hz P:0.0528 F:19903.33 Hz P:0.0975 F:19916.67 Hz P:0.1271 F:19905.00 Hz P:0.0499

Group3 horn_new anvil_newlevel 1 F:20096.67 Hz P:0.0664 F:20028.33 Hz P:0.0646 F:19900.00 Hz P:0.0890 F:20103.33 Hz P:0.0728 F:19896.67 Hz P:0.0533 F:20091.67 Hz P:0.0777 F:19901.67 Hz P:0.0817 F:20115.00 Hz P:0.0778 F:19898.33 Hz P:0.0884 F:19898.33 Hz P:0.0607

Group3 horn_new anvil_newlevel 2 F:19910.00 Hz P:0.0799 F:19908.33 Hz P:0.1276 F:19908.33 Hz P:0.0816 F:19918.33 Hz P:0.0733 F:19931.67 Hz P:0.1033 F:19910.00 Hz P:0.1466 F:19923.33 Hz P:0.1572 F:19921.67 Hz P:0.0598 F:19926.67 Hz P:0.0373 F:19903.33 Hz P:0.0660

Group4 horn_new anvil_newlevel 0 F:20045.00 Hz P:0.0745 F:20078.33 Hz P:0.0669 F:19915.00 Hz P:0.0950 F:19906.67 Hz P:0.0938 F:19915.00 Hz P:0.0661 F:19968.33 Hz P:0.0872 F:19911.67 Hz P:0.1181 F:20081.67 Hz P:0.0686 F:19906.67 Hz P:0.0759 F:19921.67 Hz P:0.0982 F:19915.00 Hz P:0.0904 F:19906.67 Hz P:0.0770 F:19915.00 Hz P:0.0649 F:19911.67 Hz P:0.0878 F:19900.00 Hz P:0.0709 F:19920.00 Hz P:0.1070 F:19905.00 Hz P:0.0833 F:19918.33 Hz P:0.0775 F:19903.33 Hz P:0.0728 F:20063.33 Hz P:0.0570

Group4 horn_new anvil_newlevel 1 F:20080.00 Hz P:0.0517 F:19913.33 Hz P:0.0461 F:19900.00 Hz P:0.0638 F:19891.67 Hz P:0.0701 F:19900.00 Hz P:0.0724 F:20085.00 Hz P:0.0890 F:19913.33 Hz P:0.0820 F:20106.67 Hz P:0.0914 F:19896.67 Hz P:0.0733 F:19895.00 Hz P:0.0610

Group4 horn_new anvil_newlevel 2 F:19910.00 Hz P:0.1295 F:19938.33 Hz P:0.1005 F:19923.33 Hz P:0.0980 F:19900.00 Hz P:0.0718 F:19906.67 Hz P:0.0766 F:19911.67 Hz P:0.0575 F:19908.33 Hz P:0.0734 F:19913.33 Hz P:0.0562 F:19978.33 Hz P:0.0496 F:19943.33 Hz P:0.0418

Group5 horn_old anvil_oldlevel 0 F:20033.33 Hz P:0.0736 F:20031.67 Hz P:0.0694 F:20026.67 Hz P:0.0475 F:20033.33 Hz P:0.0609 F:19898.33 Hz P:0.0534 F:19898.33 Hz P:0.0864 F:20036.67

Hz P:0.0685 F:19895.00 Hz P:0.0914 F:20030.00 Hz P:0.0698 F:19991.67 Hz P:0.0454 F:19903.33 Hz P:0.0440 F:19891.67 Hz P:0.1178 F:20025.00 Hz P:0.0438 F:19895.00 Hz P:0.0722 F:20033.33 Hz P:0.0640 F:19890.00 Hz P:0.0466 F:19903.33 Hz P:0.0905 F:19890.00 Hz P:0.1242 F:19886.67 Hz P:0.0542 F:19993.33 Hz P:0.0475 F:19991.67 Hz P:0.0613 F:19888.33 Hz P:0.0507 F:19900.00 Hz P:0.0579 F:19906.67 Hz P:0.0359 F:20031.67 Hz P:0.0558

Group5 horn_old anvil_oldlevel 1 F:19883.33 Hz P:0.1227 F:19878.33 Hz P:0.0771 F:19881.67 Hz P:0.0912 F:19881.67 Hz P:0.0695 F:19906.67 Hz P:0.0483 F:19880.00 Hz P:0.0787 F:19873.33 Hz P:0.0650 F:19890.00 Hz P:0.0709 F:19881.67 Hz P:0.0759

Group5 horn_old anvil_oldlevel 2 F:19878.33 Hz P:0.0855 F:19886.67 Hz P:0.1775 F:19875.00 Hz P:0.0768 F:19878.33 Hz P:0.0714 F:19916.67 Hz P:0.1557 F:19903.33 Hz P:0.2033 F:19908.33 Hz P:0.0864 F:19898.33 Hz P:0.1078 F:19901.67 Hz P:0.1391 F:19893.33 Hz P:0.1945

iii. Calculate the average f and P for each combination of tool condition and contamination level. You will need to calculate 4 × 3 = 12 numbers for both f and P .

for AE:

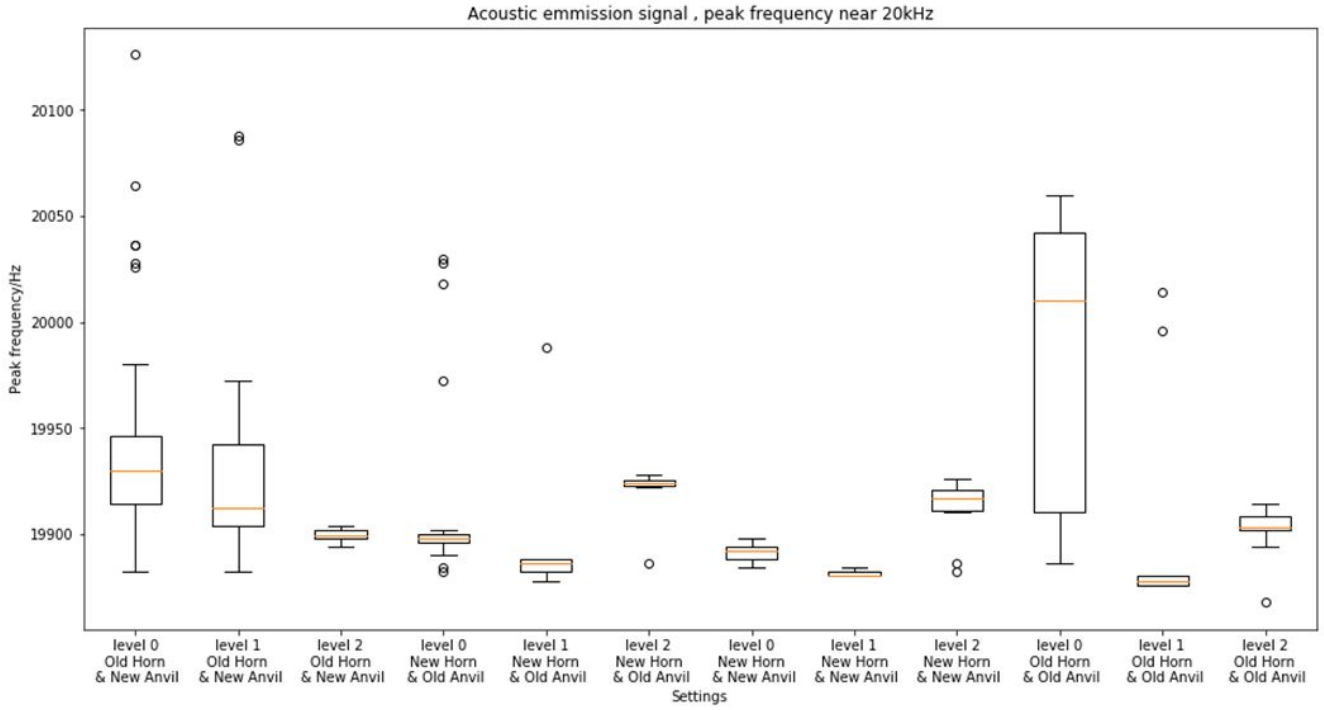
f	horn_old anvil_new	horn_new anvil_old	horn_new anvil_new	horn_old anvil_old
Level0	19890.67	19903.33	19923.75	19910.47
Level1	19882.00	19887.50	19943.83	19877.96
Level2	19913.67	19912.33	19903.67	19903.50
P	horn_old anvil_new	horn_new anvil_old	horn_new anvil_new	horn_old anvil_old
Level0	0.0285	0.0295	0.0178	0.0309
Level1	0.0476	0.0268	0.0234	0.0412

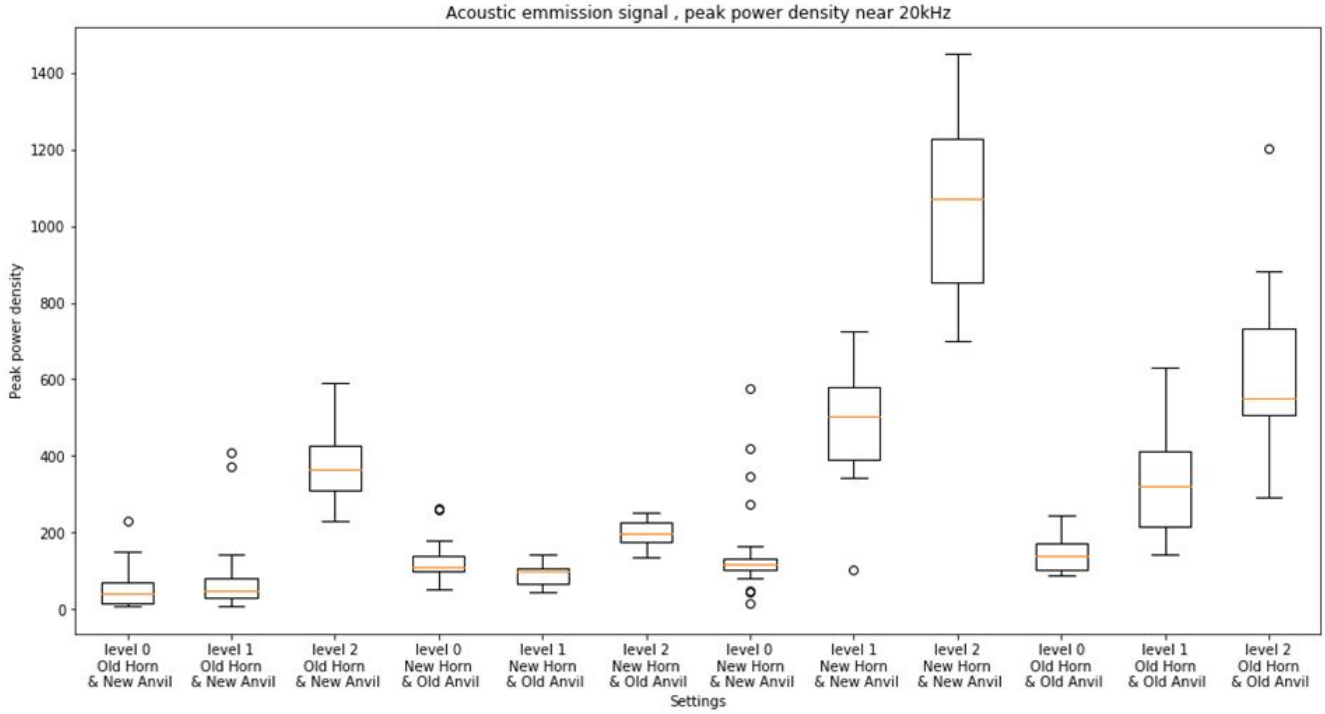
Level2	0.0661	0.0345	0.0415	0.0546

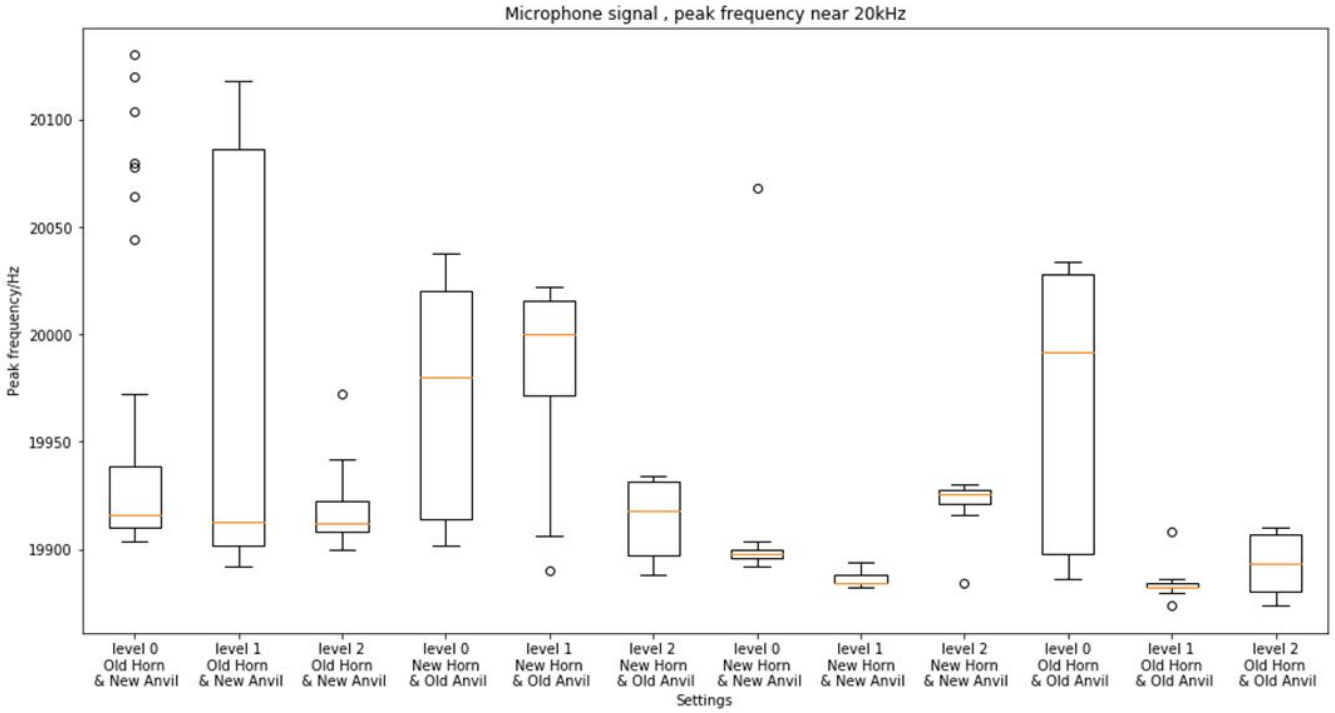
for Microphone

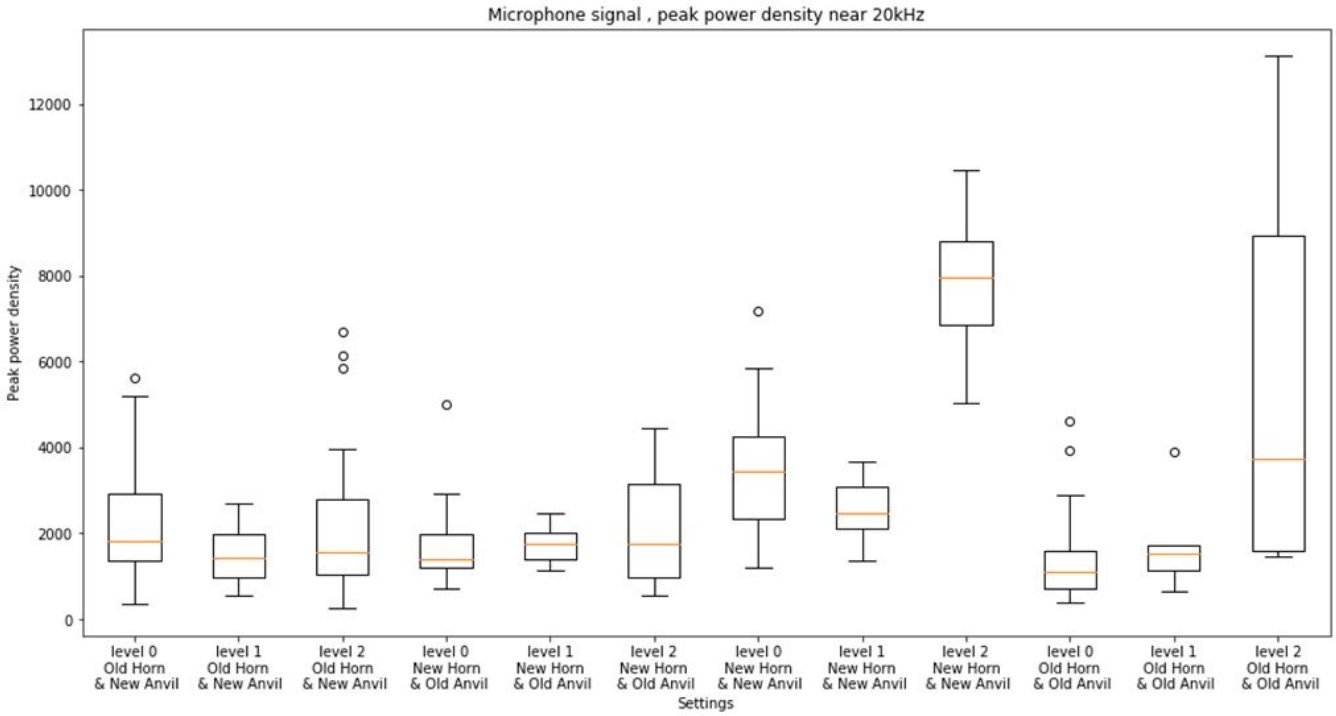
f	horn_old anvil_new	horn_new anvil_old	horn_new anvil_new	horn_old anvil_old
Level0	19904.13	19972.73	19945.42	19956.20
Level1	19885.33	19987.00	19958.17	19884.07
Level2	19923.00	19919.33	19923.33	19894.00
P				
Level0	0.1049	0.0697	0.0816	0.0653
Level1	0.0924	0.0734	0.0701	0.0777
Level2	0.1805	0.0866	0.0755	0.1298

iv. Plot box plots for f and P against the condition combinations.


Acoustic emmission signal , peak frequency near 20kHz
Peak frequency/Hz
20100
20050
20000
19950
19900
level 0 Old Horn & New Anvil
level 1 Old Horn & New Anvil
level 2 Old Horn & New Anvil
level 0 New Horn & Old Anvil
level 1 New Horn & Old Anvil
level 2 New Horn & Old Anvil
level 0 New Horn & New Anvil
level 1 New Horn & New Anvil
level 2 New Horn & New Anvil
level 0 Old Horn & Old Anvil
level 1 Old Horn & Old Anvil
level 2 Old Horn & Old Anvil
Settings


Acoustic emmission signal , peak power density near 20kHz
Peak power density
1400
1200
1000
800
600
400
200
0
level 0 Old Horn & New Anvil
level 1 Old Horn & New Anvil
level 2 Old Horn & New Anvil
level 0 New Horn & Old Anvil
level 1 New Horn & Old Anvil
level 2 New Horn & Old Anvil
level 0 New Horn & New Anvil
level 1 New Horn & New Anvil
level 2 New Horn & New Anvil
level 0 Old Horn & Old Anvil
level 1 Old Horn & Old Anvil
level 2 Old Horn & Old Anvil
Settings





v. Summarize your findings from iii and iv.

From part iii, an increase in the contamination level correlated to an increase in the power value. Old horns resulted in higher power values compared to new horns, and new anvils resulted in higher power values compared to old anvils. Thus, for highest average power value, the corresponding settings are: High contamination, old horn, and new anvil. In terms of

average frequency, a change in surface contamination and tool equipment did not affect the peak frequency, since all peak frequencies averaged around a value of 19kHz.

From part iv, the microphone peak frequencies and power densities seem to have larger variability overall than the acoustic graphs. For peak frequency, we point out that the significantly large variabilities result from multi-modality of the spectrum, after careful examination. By plotting the spectrum, it is clear that there are usually two peaks of similar height under such situations; taking the higher one only will definitely cause higher variability in peak frequency, and relatively smaller variability in peak power density. (There are some ambiguities in this "peak statistics" because there could be several peaks, and each peak could have different shapes.)
For both AE signal and microphone signal, there is a trend that the peak power density and its variance increases with higher contamination level. No explicit relationship between tool wear conditions and these features can be observed.

(4) Report the contributions of each team member in experiment, data analysis, and lab report writing.

Member Name (Credit Hours)	Contribution
Zhiqiao Dong (4)	**Experiment:** Saved data for ½ level 0 samples, transport copper for ½ level 0 samples and cut copper for level 1 & level 2 samples. **Data Analysis:** Reorganized the first version code into several functions and improved the code performance. Plotted all figures. Wrote the smoother used for the spectral analysis. **Lab Report:** Provided the template of report. Reviewed analysis for Problem (1), commented on Problem (2) and rewrote part of the analysis of Problem (3).
Yulun Wu (4)	**Experiment:**Welded for level 1 samples, saved data for level 2 samples, transport copper for level 2 samples **Data Analysis:** Finish the first version code and draw the figures and record the data used in Q1, Q2 and part of Q3 **Lab Report:** Analyze Q1, Q2 and Q3.
Evan Cali (3)	**Experiment:** Cut copper for ½ of level 0 samples, Cleaned copper for ½ of level 0 samples, welded level 1 samples, saved data for level 2 samples **Data Analysis:** Reviewed Python code for Problem (1), Completed analysis for Problem (1)

	Lab Report: Wrote analysis for Problem (1), Created & shared Google document, report formatting
Megan Voris (3)	**Experiment:** Cleaned copper for ½ of level 0 samples and cut copper strips for other ½ of level 0 samples. Welded level 2 samples **Data Analysis:** Reviewed Python code for Problem (3), Worked on analysis for Problem (3) **Lab Report:** Added analysis to Problem (2) and (3)
Allen Ho (3)	**Experiment:** Welded for level 0 samples, saved data for level 1 samples, cleaned copper for level 2 samples **Data Analysis:** Reviewed Python code for Problem (2), Completed analysis for Problem (2) **Lab Report:** Wrote analysis for Problem (2) and parts of Problem (3)