Techniques to Effectively EDM Bi-Metal Cavities

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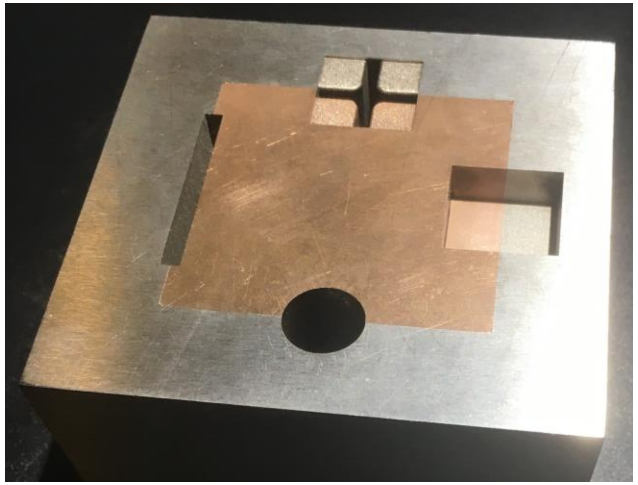
Outline

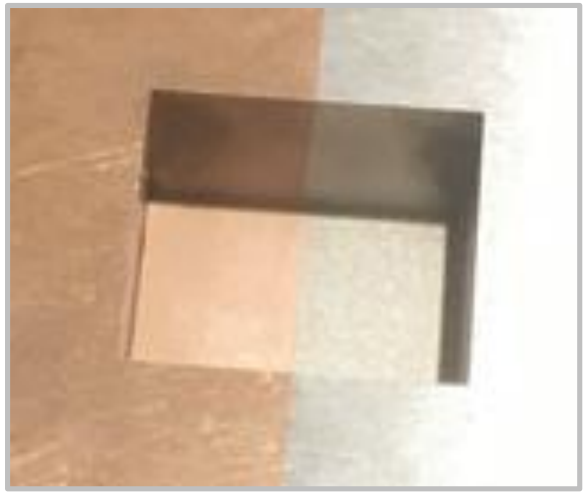
Techniques to Effectively EDM Bi-Metal Cavities

- Use of bi-metals in molding applications
  - Advantage
  - Challenges
- Understanding the material properties
  - Physical properties of workpiece/electrode materials
  - Why this is important
- Effective EDM techniques using graphite electrodes
  - Material selection
  - Test results

Use of Bi-Metals in Sinker EDM Applications

- The use of Sinker EDM to machine two different metals concurrently is one of the more challenging applications faced by end-users. We are more frequently being asked to provide assistance with material selection and EDM parameters for end users attempting to machine two metals simultaneously.
- The most common application is in mold building where copper alloys are strategically inserted in areas of the mold detail to dissipate heat away from the cavity and improve cycle times in the molding process.
- Bi-metal applications have also been found in aerospace and power generation applications, where the EDM detail is crossing two metals in an assembly or where an area of the detail has been welded. The two metals in this example may be a high nickel alloy and cobalt.
- Although this presentation will focus on mold building application, the challenge faced by operator are the same and must be approached in the same way.



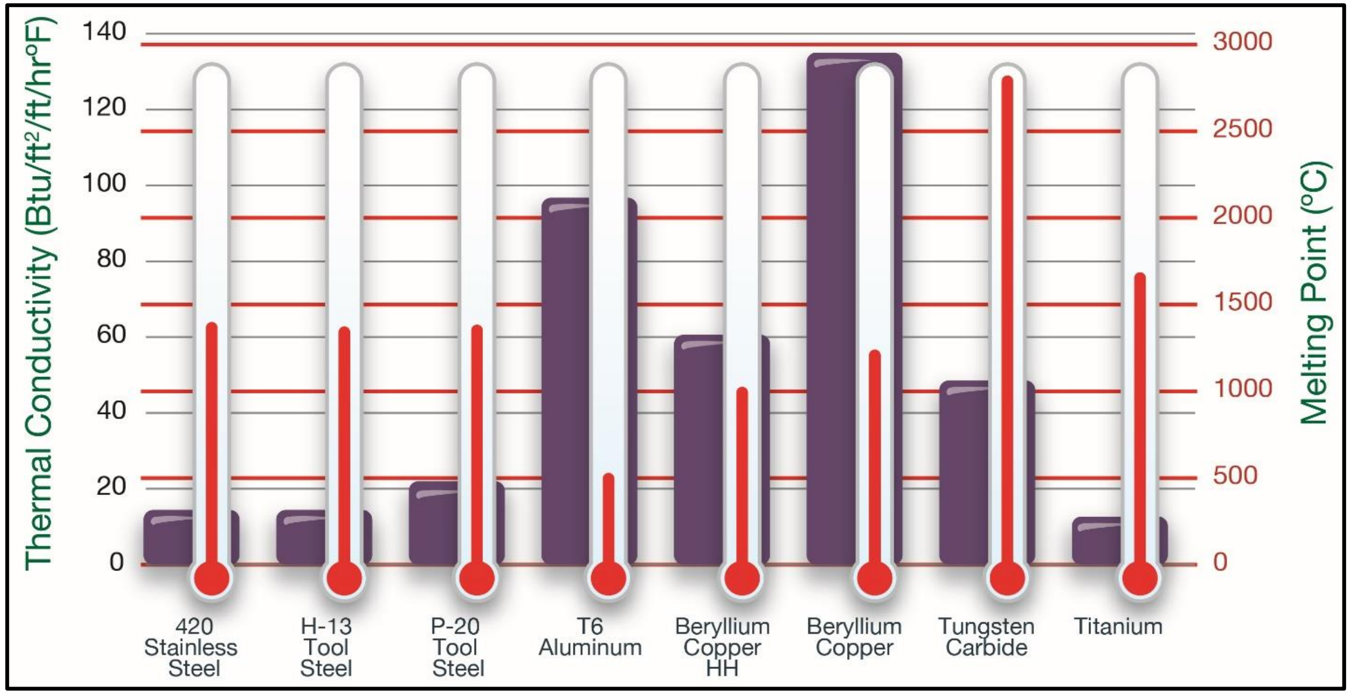


Use of Bi-Metals in Molding Applications

- The challenge exists when the mold detail falls across both tool steel and a copper alloy insert, because the two metals have significantly different physical properties.
  - Standard EDM Settings for tool steel do not yield the same results when EDMing a copper alloy.
- Because the standard approach does not yield accurate results, the moldmaker may resort to EDMing the details separately. This is commonly observed in the field, but may require:
  - Multiple part set-ups
  - Additional electrodes
  - Multiple EDM operations
- This results in additional machining time for both the electrode fabrication and EDM, and leads to higher manufacturing costs.
- With these additional efforts, the bi-metal detail may not match-up in the mold correctly causing a mismatch and the part to be out of tolerance. This would require additional machining or re-manufacturing these detail inserts.

Factors impacting EDM performance

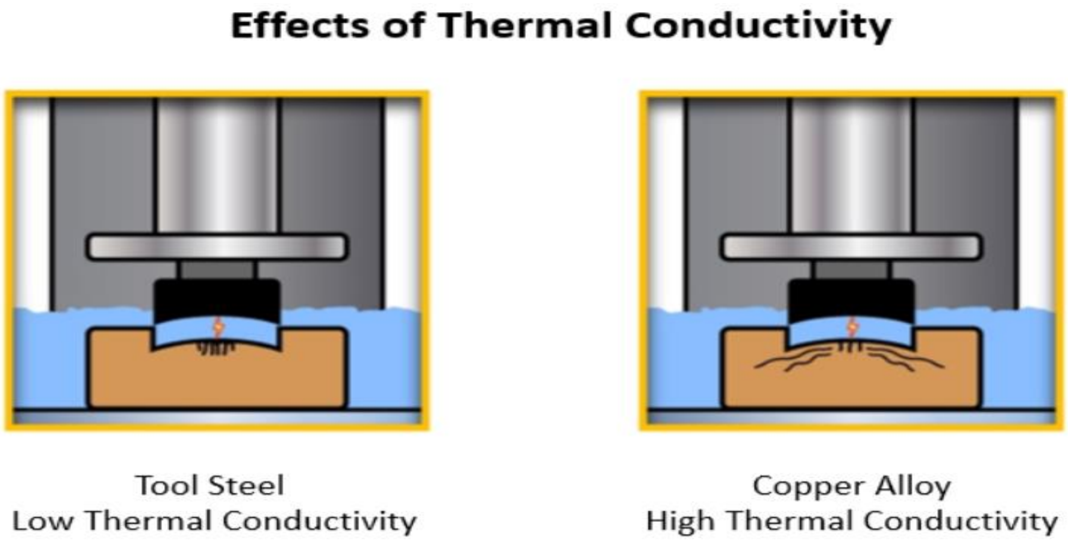
- Before you can successfully machine these two work metals, you must first understand the properties that affect performance in EDM.
- The three critical elements in any work metal that impact EDM performance are:
  - Thermal conductivity*
  - Melting point
  - Elemental makeup



Thermal conductivity represented by the purple columns for each work metal in the chart.

Thermal Conductivity affect on EDM Parameters

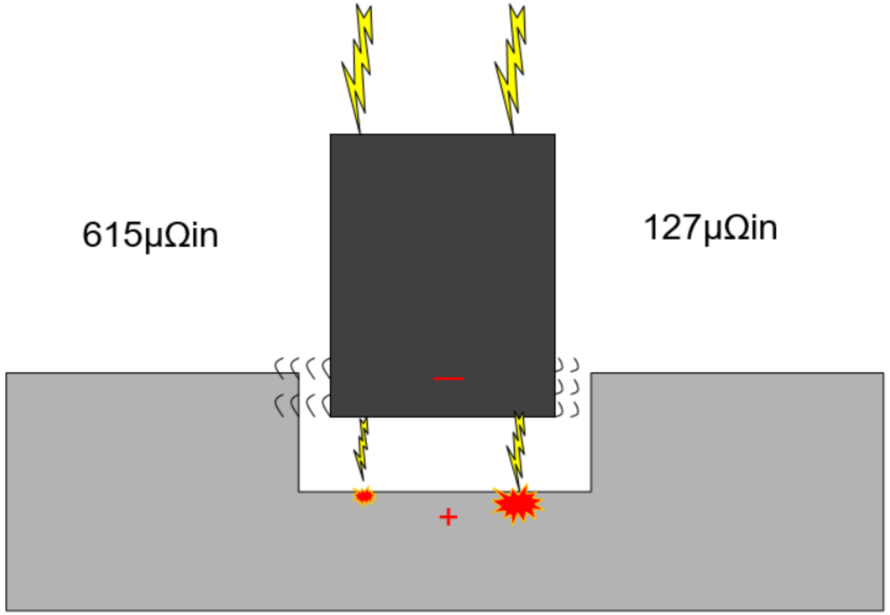
- Tool Steel has a low thermal conductivity when compared to other work metals. This is one of the primary factors that makes it a relatively easy material to EDM.
  - Holds thermal energy where the spark occurs
  - Machines well in positive polarity, longer on-time
  - Allows for electroplating
  - Good combination of speed and wear



- Copper Alloys generally have a high Thermal Conductivity. As a result, thermal energy quickly dissipates away from the point of the spark.
  - Standard EDM conditions are inefficient
  - Electrode wear increases
  - Maintaining spark intensity requires a different approach

Electrode Selection for High Thermally Conductive Material

- To effectively EDM work metals with high thermally conductivity, the follow parameters need to be changed

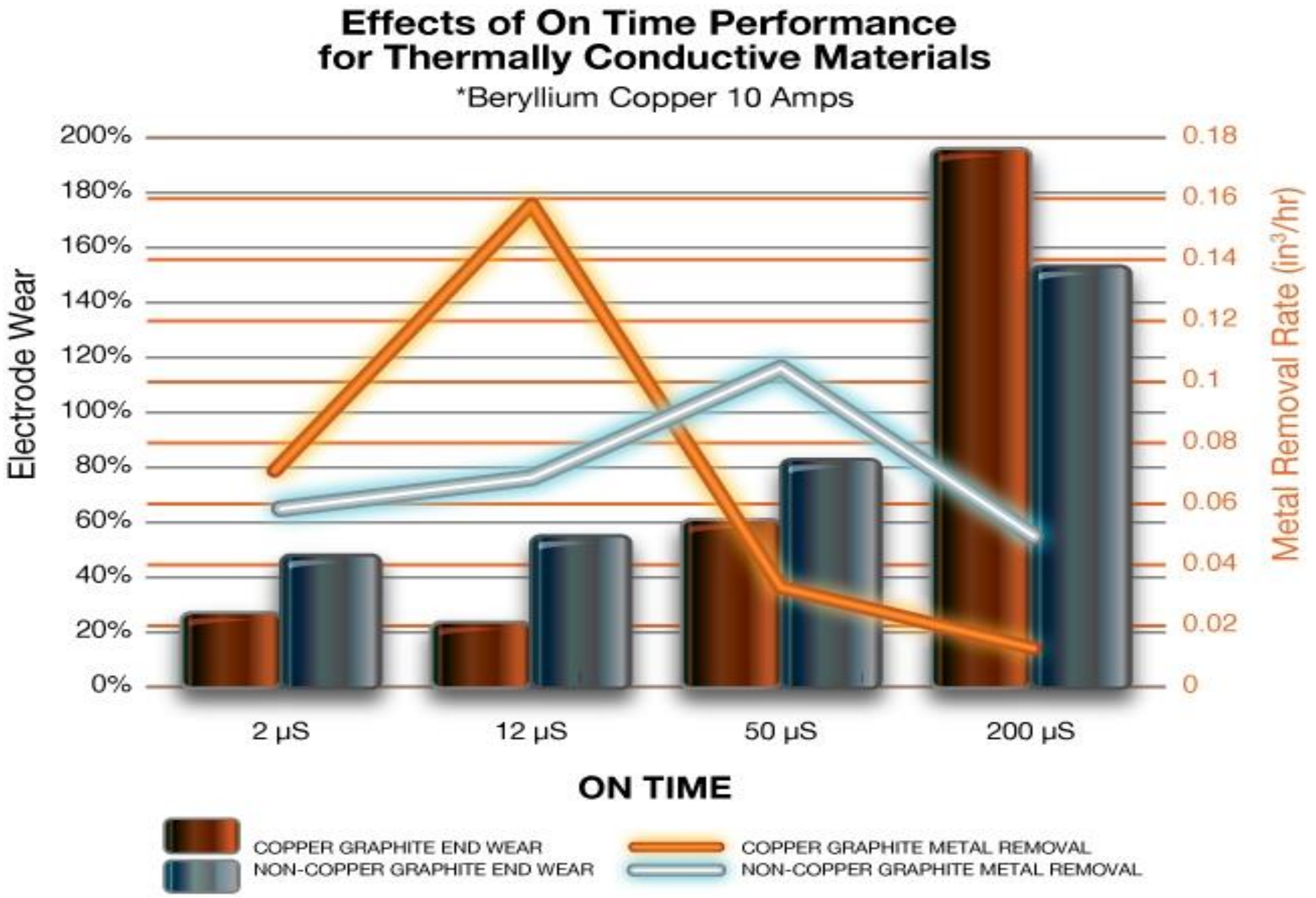


- Reverse polarity
- Lower on-times
- Higher peak amperage
- Copper impregnated graphite lower electrical resistivity

127 µΩin -   Copper impregnated graphite (EDM-C3)

615 µΩin -   Non-impregnated graphite (EDM-3)

- Graphite electrode material with a lower electrical resistivity will deliver a spark with greater intensity to the detail.
- This increased spark intensity further optimizes the EDM parameters that are needed for high thermally conductive materials.


Effects of On Time Performance
for Thermally Conductive Materials
*Beryllium Copper 10 Amps
Electrode Wear
200%
180%
160%
140%
120%
100%
80%
60%
40%
20%
0%
Metal Removal Rate (in³/hr)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
2 µS
12 µS
50 µS
200 µS
ON TIME
COPPER GRAPHITE END WEAR
NON-COPPER GRAPHITE END WEAR
COPPER GRAPHITE METAL REMOVAL
NON-COPPER GRAPHITE METAL REMOVAL

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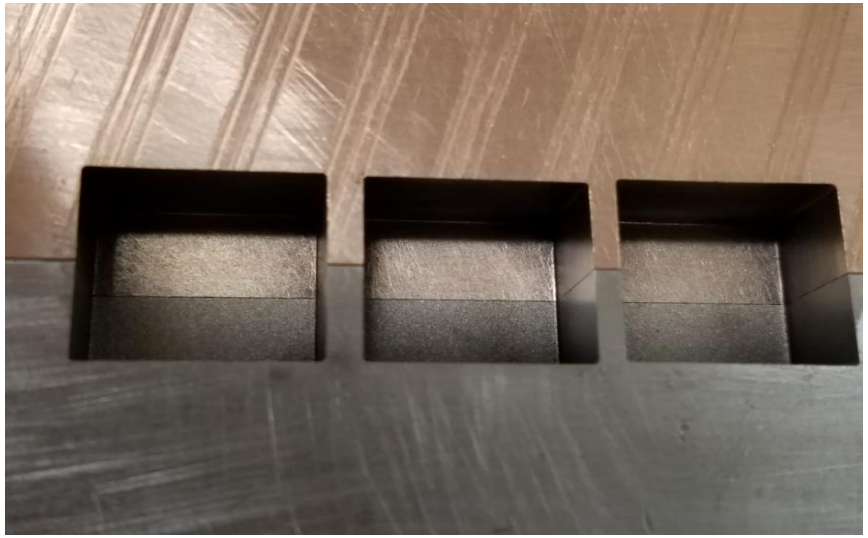
Test Parameters for Bi-Metal Analysis

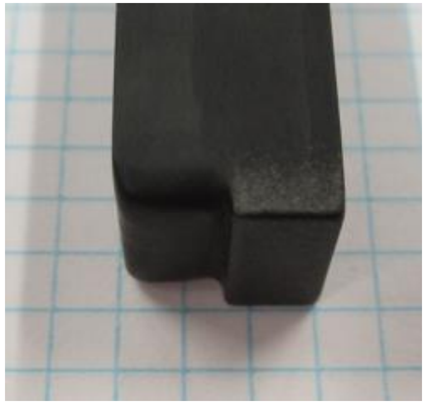
- In order to demonstrate the effects of EDM Parameters and Electrode selection when EDMing tool steel and copper alloys concurrently, trials were conducted to test the effect of varying EDM parameters. Below are the details of the tests conducted:
  - Electrode size: 0.500” x 0.500”
  - Program depth: 0.375”
  - Surface finish: 20 VDI
  - Adaptive control: Off
  - Flushing: Side flushing/Jump cycle
  - Undersize: 0.010”per side
  - Electrode quantity: 4 each
  - Mismatch target: </= 0.0005”
- The following parameters were testing using both EDM-3 and EDM-C3 as the electrode material:
  - Steel Settings
    - 40 peak amps/75 on-time in roughing
    - 11 settings stepping down to finish
    - Positive and negative polarity
  - Copper Alloy Settings
    - 80 peak amps/12 on-time in roughing
    - 9 settings stepping down to finish
    - Positive and negative polarity



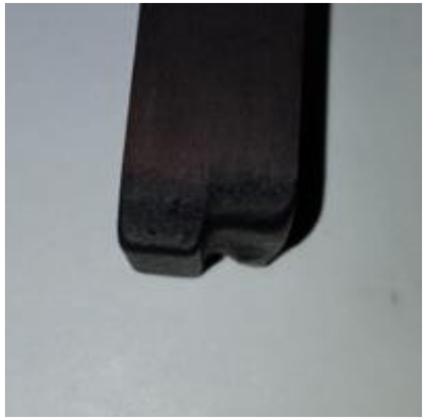
Test 1: Bi-Metals with Steel Settings

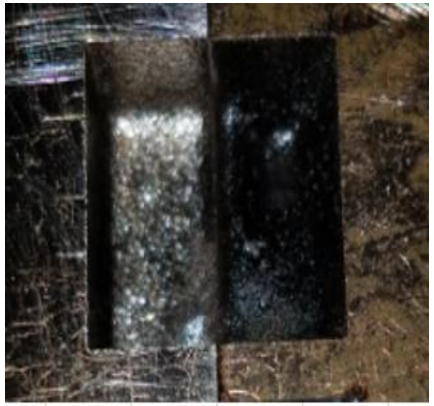
- As expected, machining this detail in positive polarity proved to be ineffective using both electrode material.
    - **Positive Polarity**
        - 40 Peak Amps/75 on-time in roughing
- The results of typical positive polarity steel settings worked well on the steel material, but poorly on the copper alloy material.
- This is primarily due to the difference in thermal conductivity between the two materials.
- Ultimately both tests were stopped prematurely due the ineffective cutting conditions.

Positive Polarity		Steel Side			Copper Alloy Side		
Electrode 1	Time	Depth of Cut	Avg. End Wear	Average EW%	Depth of Cut	Avg. End Wear	Average EW%
EDM-3	1:00:00	0.221”	0.0025”	1%	0.188”	0.0435”	20%



Positive Polarity		Steel Side			Copper Alloy Side		
Electrode 1	Time	Depth of Cut	Avg. End Wear	Average EW%	Depth of Cut	Avg. End Wear	Average EW%
EDM-C3	1:00:00	0.267”	0.027”	10%	0.218”	0.1165”	63%



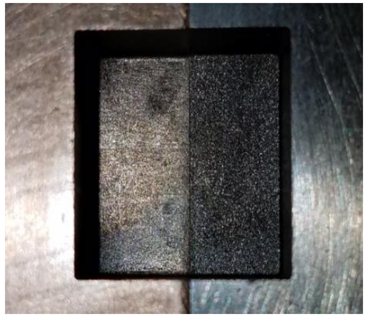


Test 2: Bi-Metals with Steel Settings

- This test was designed to use test 1 conditions while reversing polarity.
  - **Negative Polarity**
    - 40 Peak Amps/75 on-time in roughing
- In a typical steel applications you would expect to see an increase in both end wear and metal removal rate.
- The results of this test were a significant improvement to Test 1.
- The EDM-3 test result show an increase in electrode wear and ultimately would have required at least 1 additional electrode to finish the detail.
- The EDM-C3 test was successful, however a comparison to copper alloy settings is necessary to determine the effectiveness.

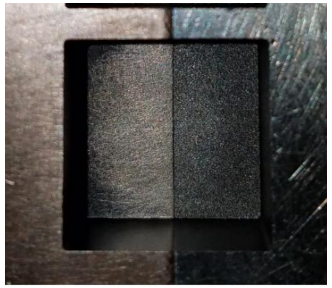
Negative Polarity		Steel Side			Copper Alloy Side		
EDM-3	Avg. Time	Depth of Cut	Avg. End Wear	Average EW%	Depth of Cut	Avg. End Wear	Average EW%
Electrode 1	0:39:36	0.284”	0.059”	19%	0.284”	0.130”	46%
Electrode 2	0:22:30	0.364”	0.0095”		0.362”	0.008”	
Electrode 3	0:16:30	0.372”	0.002”		0.370”	0.0045”	
Electrode 4	0:14:36	0.3735”	0.001”		0.372”	0.0025”	
Total Time*	01:33:12	*Additional Electrodes would have been required					





Negative Polarity		Steel Side			Copper Alloy Side		
EDM-C3	Avg. Time	Depth of Cut	Avg. End Wear	Average EW%	Depth of Cut	Avg. End Wear	Average EW%
Electrode 1	1:01:20	0.329”	0.0455”	14%	0.3195”	0.0575”	17%
Electrode 2	0:21:51	0.3695”	0.0055”		0.3675”	0.0085”	
Electrode 3	0:15:47	0.3745”	0.0005”		0.372”	0.003”	
Electrode 4	0:13:39	0.3745”	NW		0.374”	0.0005”	
Total Time*	1:52:37	**Successful Test**					

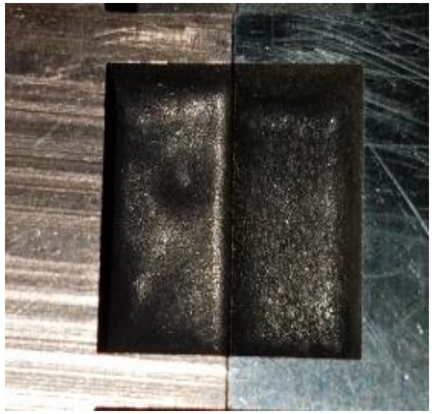




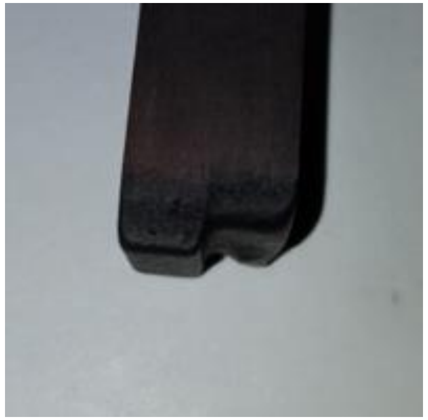
Test 3: Bi-Metals with Copper Alloy Settings

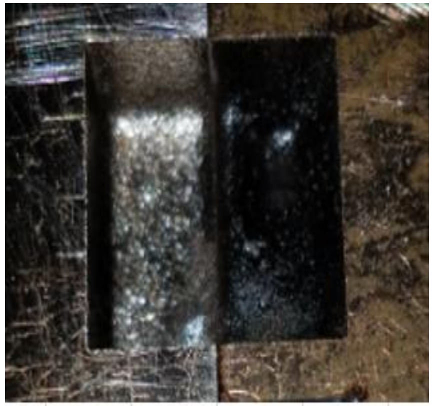
- Based on the results from positive steel settings, the expectations of this test were low.
  - **Positive Polarity**
    - 80 Peak Amps/12 on-time in roughing
- With both electrode materials, the burn itself was very unstable and inefficient.
- Because of the increase in amperage and reduction in on-time, we saw an additional increase in end wear.
- Ultimately both tests were stopped prematurely due the ineffective cutting conditions.

Positive Polarity		Steel Side			Copper Alloy Side		
Electrode 1	Time	Depth of Cut	Avg. End Wear	Average EW%	Depth of Cut	Avg. End Wear	Average EW%
EDM-3	1:00:00*	0.1865”	N/A	N/A	0.135”	N/A	N/A



Positive Polarity		Steel Side			Copper Alloy Side		
Electrode 1	Time	Depth of Cut	Avg. End Wear	Average EW%	Depth of Cut	Avg. End Wear	Average EW%
EDM-C3	1:25:00*	0.3005”	0.0985”	32%	0.2985”	0.076”	25%

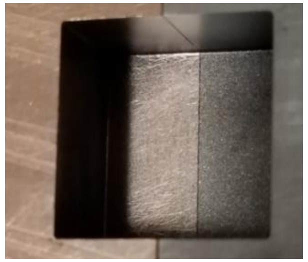




Test 4: Bi-Metals with Copper Alloy Settings

- This test was designed to use the EDM parameters that are recommended for materials with high thermal conductivity.
  - **Negative Polarity**
    - 80 Peak Amps/12 on-time in roughing
- In a copper alloy application these parameters are known to provide the best results for speed and electrode wear.
- The results from this test provided the best performance of the full trial.
- Both materials performed well, but EDM-C3 had the better performance of the two grades.

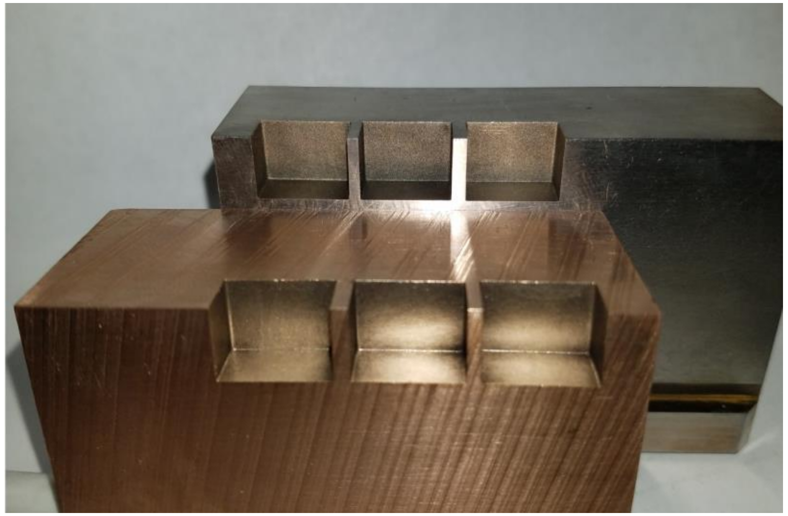
Negative Polarity		Steel Side			Copper Alloy Side		
EDM-3	Avg. Time	Depth of Cut	Avg. End Wear	Average EW%	Depth of Cut	Avg. End Wear	Averag e EW%
Electrode 1	0:39:36	0.3065”	0.072”	21%	0.291”	0.0815”	26%
Electrode 2	0:22:30	0.361”	0.013”		0.366”	0.012”	
Electrode 3	0:16:30	0.3715”	0.004”		0.373”	0.003”	
Electrode 4	0:14:36	0.374”	0.00075”		0.374”	0.00075”	
Total Time	01:47:34	Successful Test- Mismatch for each test was within 0.0005”					



Negative Polarity		Steel Side			Copper Alloy Side		
EDM-C3	Avg. Time	Depth of Cut	Avg. End Wear	Average EW%	Depth of Cut	Avg. End Wear	Average EW%
Electrode 1	1:00:48	0.318”	0.05475”	17%	0.321”	0.055”	18%
Electrode 2	0:26:13	0.364”	0.010”		0.368”	0.007”	
Electrode 3	0:11:34	0.371”	0.0011”		0..372”	0.0008”	
Electrode 4	0:08:39	0.3745”	0.0003”		0.374”	0.00025”	
Total Time	1:45:04	Successful Test					

Summary of Test Results

- The test results support the original hypothesis that a material with a high thermal conductivity must be approached in negative polarity, even when it is paired with a material with low thermal conductivity.
- This will hold true whether you are in a mold application where steel/copper alloys are combined, or in aerospace application where nickel alloy/cobalt may be combined.
- In short, the parameters for the more difficult material to EDM must be respected when machine two metals at one time.
- The test also revealed that a copper impregnated graphite will provide the best result; however, a standard graphite will also successfully machine the bi-metal when the right parameters are used.
- The question then changes to other key performance factors that must be considered:
  - How machinable is the detail, and can it be easily redressed?
  - Does the EDM performance improvement justify the increase material cost?
- Generally, it is found that the electrode blank cost is a small percentage of the overall job cost, and that performance criteria will dictate the material choice.
- Ultimately, it will come down to user preference and the requirements of each specific application.



Thank You

Should you have any questions or require any assistance, please feel free to contact me directly:

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