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Optimizing Bridge Plug Milling Efficiency Utilizing Weight-On-Bit to Control Debris Size: A Comparative Study of the Debris Size vs Weight-On-Bit Utilizing Five Bladed Carbide Mill, Tri-Cone and PDC Bits

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ICoTA Intervention & Coiled Tubing Association

INTRODUCTION

Objective: Analyzes the performance of the five bladed carbide mill, tri-cone and PDC bits in terms of debris size vs weight-on-bit.

1) Determine how set down force affects the drilling tool in terms of generating smaller debris size.

2) Analyze how set down force of the drilling tool affects the ROP on the bridge plug.

CONTROLLED VARIABLES

1. Motor Selection: 2-7/8” OD downhole motor inside 4-1/2” casing. The pump rate was set to 480 l/min (~3 bbl/min)

2. Composite Bridge Plug Selection: To maintain the consistency of the test results, all the plugs used in the milling experiment were provided by the same plug manufacturer.

3. Fluid Selection: Fresh water. There was no chemical such as gel or friction reducer added to influence the overall performance of the motor.

MANIPULATED VARIABLES

1. Weight on Bit (WOB): Three different WOB settings, Low, Medium, and High.

2. Plug Drilling Assembly:

a) 92.0mm/3.625” Crushed Carbide Insert Mill (Under Drift Mill)
b) 94.0mm/3.701” Crushed Carbide Insert Mill (Full Drift Mill)
c) 92.0mm/3.625” Sealed Bearing Tricone Tooth Bit, with 3 Nozzles
d) 94.0mm/3.701” Bicentre/Eccentric Crushed Carbide Insert Mill
e) 92.0mm/3.625” PDC Bit with 34.9mm cutters and 3 nozzles

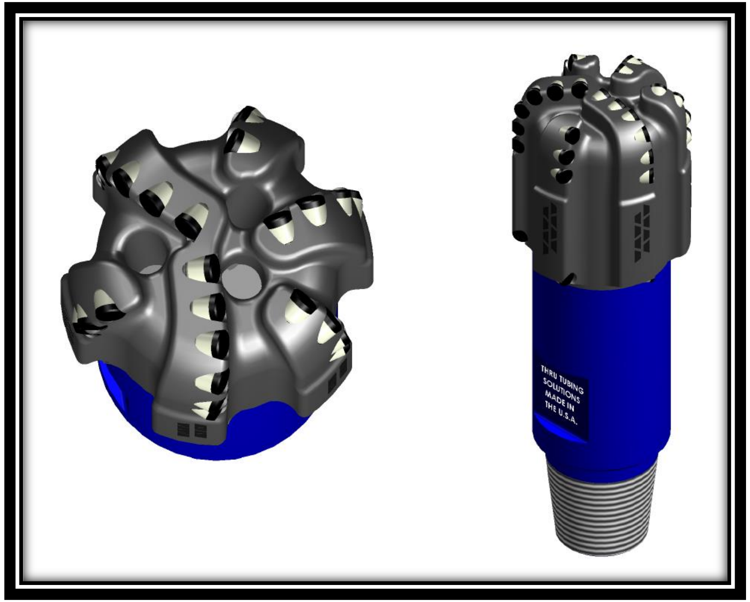
MANIPULATED VARIABLES

(Under Drift Mill/Full Drift Mill)

(Sealed Bearing Tricone Tooth Bit, with 3 Nozzles)

MANIPULATED VARIABLES

(Bicentre/Eccentric Crushed Carbide Insert Mill)



(PDC Bit with 34.9mm cutters and 3 nozzles)

MILLING SCHEDULE (MILL TYPE VS SET DOWN FORCE)

Plug #	*Mill/Bit Type*	*Set down Force*
1	*Underdrift Mill*	***low***
2	*Underdrift Mill*	***medium***
3	*Underdrift Mill*	***high***
4	*Full-drift Mill*	***low***
5	*Full-drift Mill*	***medium***
6	*Full-drift Mill*	***high***
7	*Tri-cone*	***low***
8	*Tri-cone*	***medium***
9	*Tri-cone*	***high***
10	*Offset Mill*	***low***
11	*Offset Mill*	***medium***
12	*Offset Mill*	***high***
-	-	-
13	*PDC*	***medium***
14	*PDC*	***high***

COMPOSITE BRIDGE PLUG MATERIAL

Composite Component
(Body of the plug)

Metal Component
(Cast Iron Slips)

Elastomer Components
(Packer Element)

SIEVE ANALYSIS

- A sieve analysis test or a gradation test is used to obtain the particle distribution size of the debris. This proven method is commonly used to analysis the particle size of sand and gravel.
- It is sorted based on screen sizes, the sieve with the biggest screen size is placed on the top while the sieves with the smallest screen size is placed on the bottom.

SIEVE ASSEMBLY

2.0”　　1.5”　　1.0”　　3/4”

1/2”　　3/8”　　Mesh 4　　Mesh 8　　Mesh 16

SIEVE ANALYSIS

1. Composite Component

SIEVE ANALYSIS

2. Metal Component

SIEVE ANALYSIS

3. Elastomer Component

Cumulative Percent Passing vs the Logarithmic Sieve Size (plug#1-Underdrift mill, low set down force)

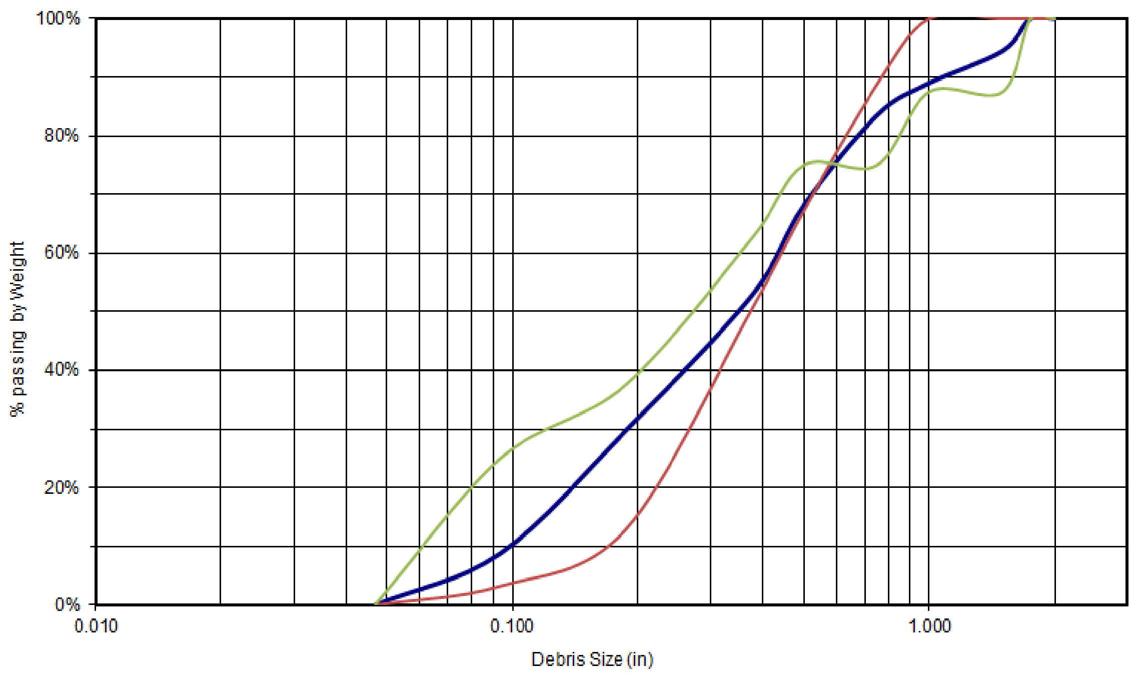


Figure 1: Debris size analysis for Plug 1

SIEVE ANALYSIS

- In order to obtain a percentage retained per each sieve sizes, the weight of debris of each sieve is divided by the total weight of the debris.

- In first analysis, **the focus was on the larger pieces of debris retained by the sieve with the larger opening**. **20% of the weight retained in sieve (80% passing by weight)** was selected as the cut off point for the analysis

- What's the biggest cutting size from each drilling assembly?

Cumulative Percent Passing vs the Logarithmic Sieve Size (plug#1-Underdrift mill, low set down force)

- Biggest cutting size from each drilling assembly

20% weight retained sieve

80% passing by weight

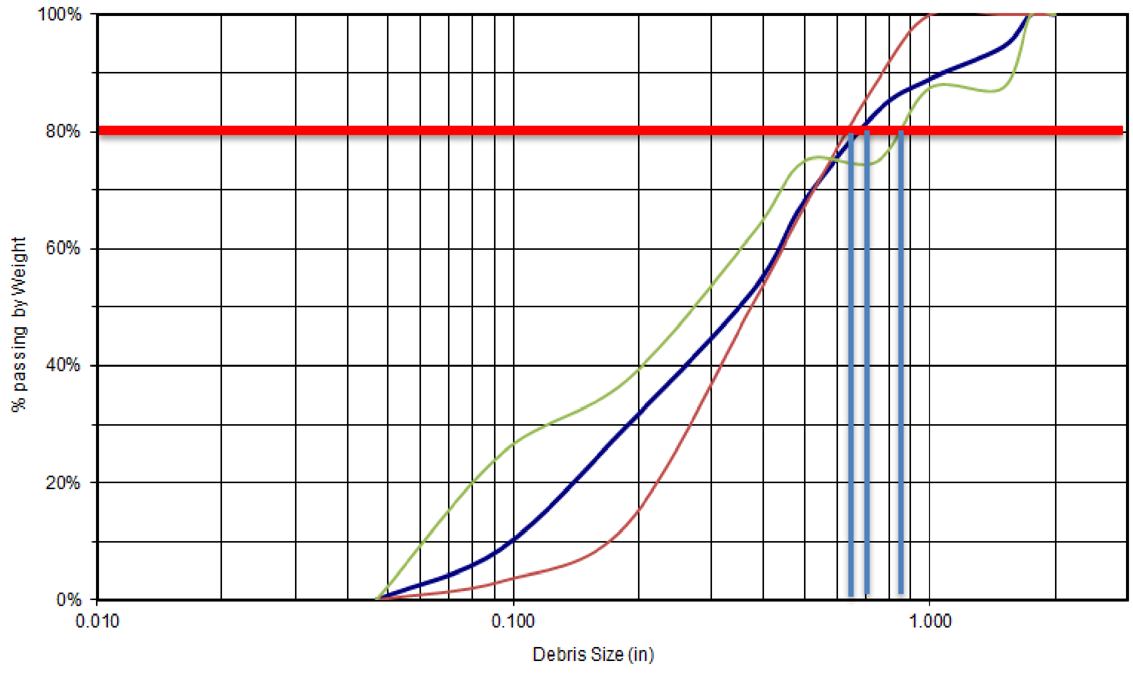


Figure 1: Debris size analysis for Plug 1

		Under Drift Mill			Full Drift Mill			Tri-cone			Offset Mill			PDC Mill		
Description	Debris Type	Plug #1	Plug #2	Plug #3	Plug #4	Plug #5	Plug #6	Plug #7	Plug #8	Plug #9	Plug #10	Plug #11	Plug #12	-	Plug #13	Plug #14
80% passing by weight	Elastomer	6	3	7	8	4	9	1	2	5	14	13	12	-	10	11
80% passing by weight	Metal	8	11	2	4	6	7	3	1	5	14	10	12	-	13	9
80% passing by weight	Composite	8	12	7	9	4	3	6	1	2	13	14	10	-	11	5
	Total	22	26	16	21	14	19	10	4	12	41	37	34	n/a	34	25
	Weight on Bit	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH

80% passing by weight (20% weight retained in sieves) Ranking based on size. Note: Ranked from #1 to #14 (Smallest debris size to the largest debris size)

- In first analysis, the focus was on the largest pieces of debris retained by the sieve with the larger opening. **20% of the weight retained in sieve (80% passing by weight)** was selected as the cut off point for the analysis

Overall Ranking (smallest to largest)	Low WOB (Overall)	Med WOB (Overall)	High WOB (Overall)
1	Tri-cone	Tri-cone	Tri-cone
2	Full Drift Mill	Full Drift Mill	Under Drift Mill
3	Under Drift Mill	Under Drift Mill	Full Drift Mill
4	Offset Mill	PDC Mill	PDC Mill
5	n/a	Offset Mill	Offset Mill

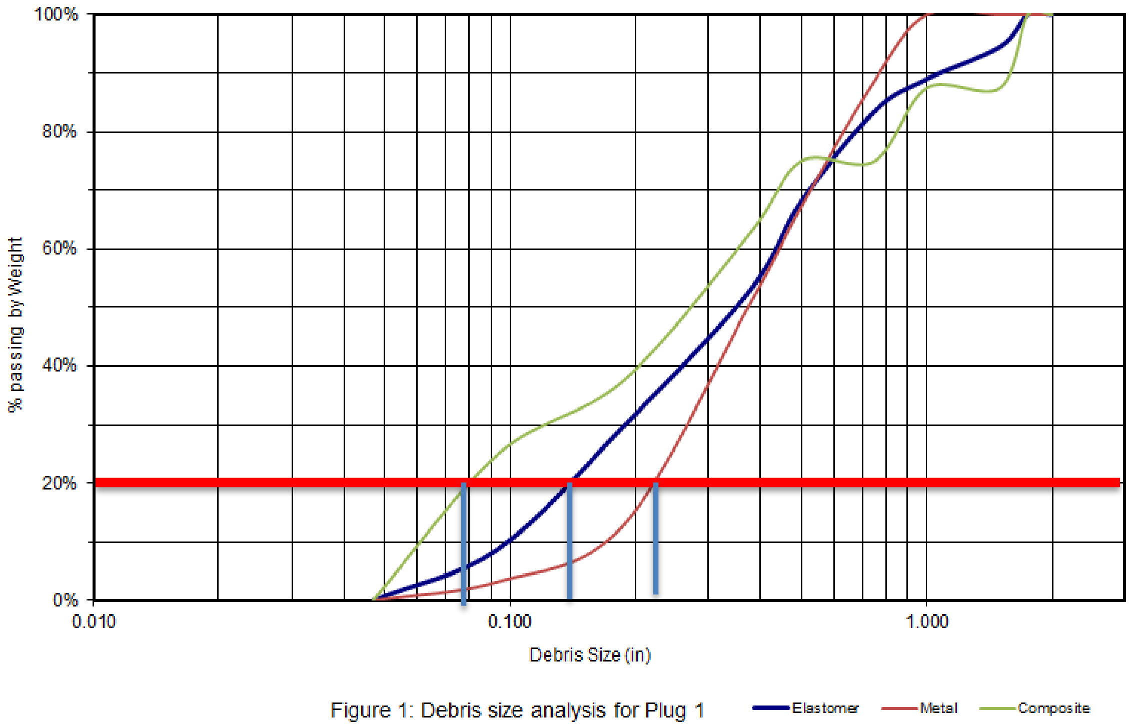
Weight on bit vs Plug Drilling Assembly 80% passing by weight (20% weight retained in sieves). Ranking based on debris size.

Cumulative Percent Passing vs the Logarithmic Sieve Size
(plug#1-Underdrift mill, low set down force)

80% weight retained sieve

20% passing by weight

- Smallest cutting size from each drilling assembly



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20% passing by weight	Elastomer	1	7	2	5	3	4	8	9	12	14	13	11	-	6	10
20% passing by weight	Metal	4	1	6	2	3	8	5	7	9	14	10	12	-	11	13
20% passing by weight	Composite	2	12	10	13	7	11	6	5	4	9	8	14	-	3	1
	Total	7	20	18	20	13	23	19	21	25	37	31	37	n/a	20	24
	Weight on Bit	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH

20% passing by weight (80% weight retained in sieves) Ranking based on size. Note: Ranked from #1 to #14 (Smallest debris size to the largest debris size)

- In second analysis, the focus was on the smallest pieces of debris retained by the sieve with the smaller opening. **80% of the weight retained in sieve (20% passing by weight)** was selected as the cut off point for the analysis.

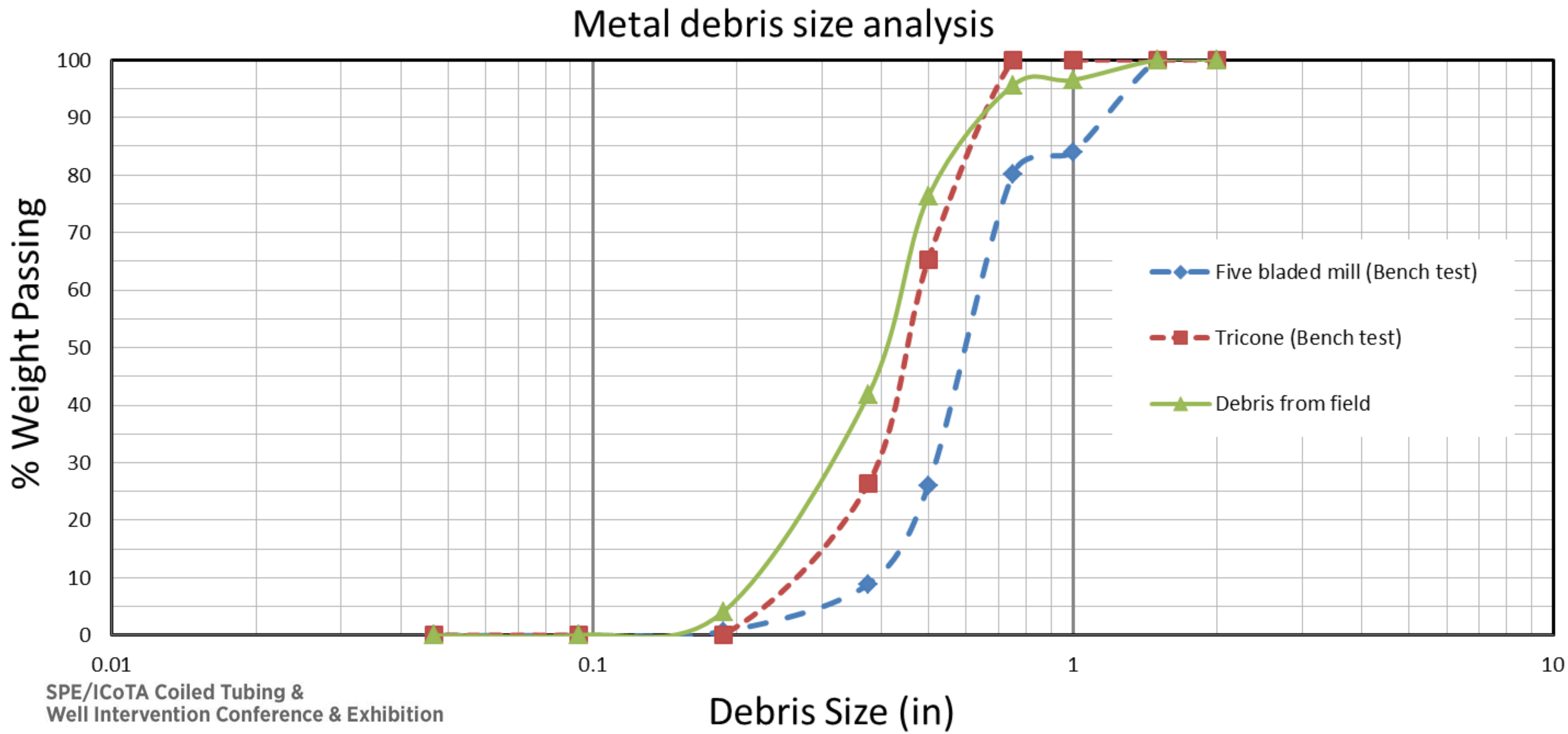
Overall Ranking (Smallest to largest)	Low WOB (Overall)	Med WOB (Overall)	High WOB (Overall)
1	Under Drift Mill	Full Drift Mill	Under Drift Mill
2	Tri-cone	Under Drift Mill	Full Drift Mill
3	Full Drift Mill	PDC Mill	PDC Mill
4	Offset Mill	Tri-cone	Tri-cone
5	n/a	Offset Mill	Offset Mill

Weight on bit vs Plug Drilling Assembly 80% passing by weight (20% weight retained in sieves). Ranking based on debris size.

MILL/BIT ROP vs WEIGHT ON BIT

	Mill/Bit ROP (in/min)					
Weight on Bit	**Under Drift Mill**	**Full Drift Mill**	**Tricone**	**Offset Mill**	**PDC**	**Average ROP Speed based on WOB**
LOW	0.205	0.212	0.001	0.627	N/A	0.261
MID	0.464	0.428	0.544	1.097	0.948	0.633
HIGH	0.924	0.477	0.448	0.235	0.518	0.521
Average ROP Speed by BHA	0.531	0.372	0.331	0.653	0.733	-
Ranked based on Speed (slowest to Fastest)	3	2	1	4	5	

FIELD DATA VS EXPERIMENTAL DATA



MILL/BIT ROP vs WEIGHT ON BIT

Weight on Bit	Mill/Bit ROP (in/min) Under Drift Mill	Full Drift Mill	Tricone	Offset Mill	PDC	Average ROP Speed based on WOB
LOW	0.205	0.212	0.001	0.627	N/A	0.261
MID	0.464	0.428	0.544	1.097	0.948	0.633
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Average ROP Speed by BHA	0.531	0.372	0.331	0.653	0.733	-
Ranked based on Speed (slowest to Fastest)	3	2	1	4	5	

Overall Ranking (smallest to largest)	Low WOB (Overall)	Med WOB (Overall)	High WOB (Overall)
1	Tricone	Tricone	Tricone
2	Full Drift Mill	Full Drift Mill	Under Drift Mill
3	Under Drift Mill	Under Drift Mill	Full Drift Mill
4	Offset Mill	PDC Mill	PDC Mill
5	n/a	Offset Mill	Offset Mill

Weight on bit vs Plug Drilling Assembly 80% passing by weight (20% weight retained in sieves). Ranking based on debris size.

- Slower ROP = smaller cuttings
- Faster ROP = larger cuttings.

CONCLUSIONS

- The weight on bit does not appear to affect the overall performance of the plug drilling assembly in terms of generating smaller cuttings
- The tri-cone produces smaller cutting sizes while the offset mill and the PDC mill produced larger cutting sizes. The under drift and the full drift mill are in the middle.
- Under drift mill and the full drift mill generate smaller fine debris particles than Tri-cone, Offset mill and PDC mill.

CONCLUSIONS

- There is a positive correlation between weight on bit and ROP for underdrift mill, full drift mill and Tri-cone
- The ROP of Offset mill and the PDC drop significant if the WOB is too high.
- There is a strong correlation between ROP and the debris sizes. Slower ROP generate smaller cuttings while faster ROP generate larger cuttings.

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