Drill Bits
Dull Grading System Upgrade

Feb 9th 2022

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Outline

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- Charter
- Progress Overview
- Advanced Dull Grading Process Map
- Grading Every Cutter – Training Examples
- Key Accomplishments
- Additional Considerations
- Next Steps

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Objective

Re-write the IADC dull grading system to better support a workflow **focused on continuous improvement and root cause analysis.**

This section of the grading system shall focus on a qualitative classification scheme of **PDC cutters, drill bits, and tools with cutting elements**, with a second priority on quantitative analysis.

Charter Statement

Create a Forensics Evaluation Workflow(s) and Best Practice(s) Document to be published within IADC and SPE.

Collect the most common cutter damage examples, group and label them according to the workgroup consensus	**X**
Define a standard set of words and descriptions for each class	**X**
Gather, label and provide to the Case Study Workgroup a large set of case study photo examples for human training and machine learning	
Document the frequency of occurrence of different degradation modes to use as a priority guide for training documents	
Review and update all other bit related codes within the current IADC system to make sure they are; needed, unique, well understood, and up to date. (Broken blades, washouts, etc.)	
Concentrate on PDC drill bits, then make this compatible with, Roller Cones, Reamers and Under Reamers, and Hybrid bits	**X**
Document the new proposed codes and resolve any conflicts with the other workgroups	**X**
Review the proposed codes, storage methods, and examples with industry experts for alignment	
Conduct an end user field trial of the new system and update codes and instructions based on feedback Repeat if required	
Create a final best practices document	

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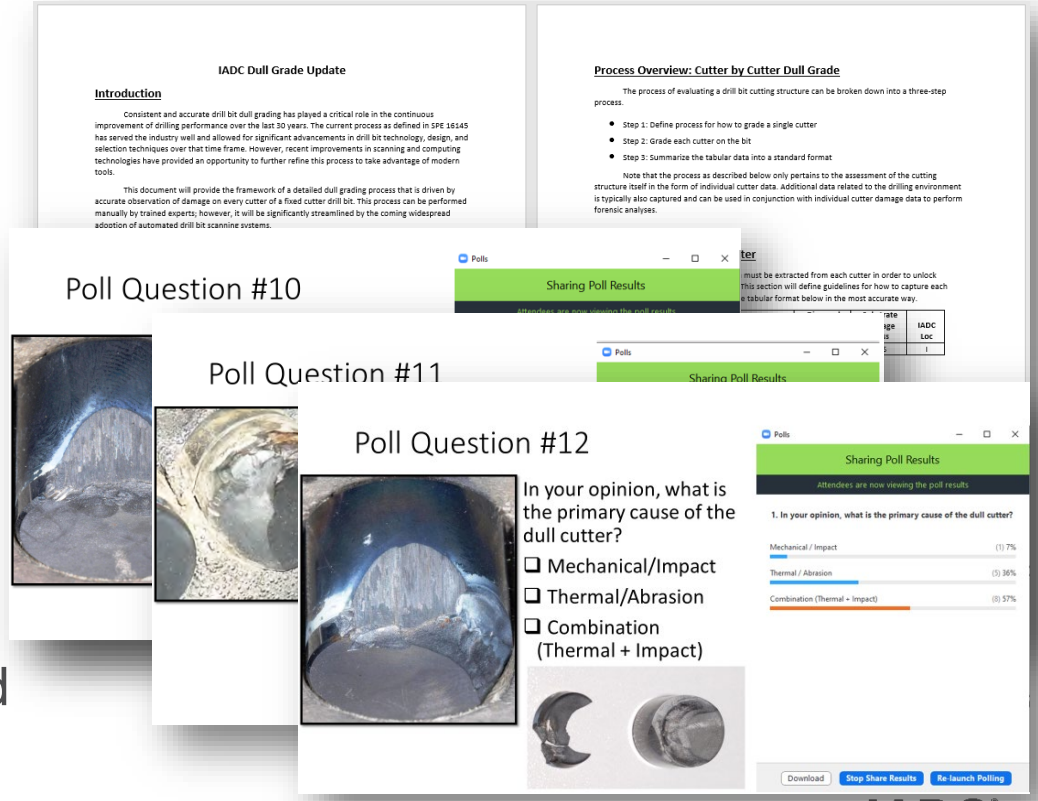
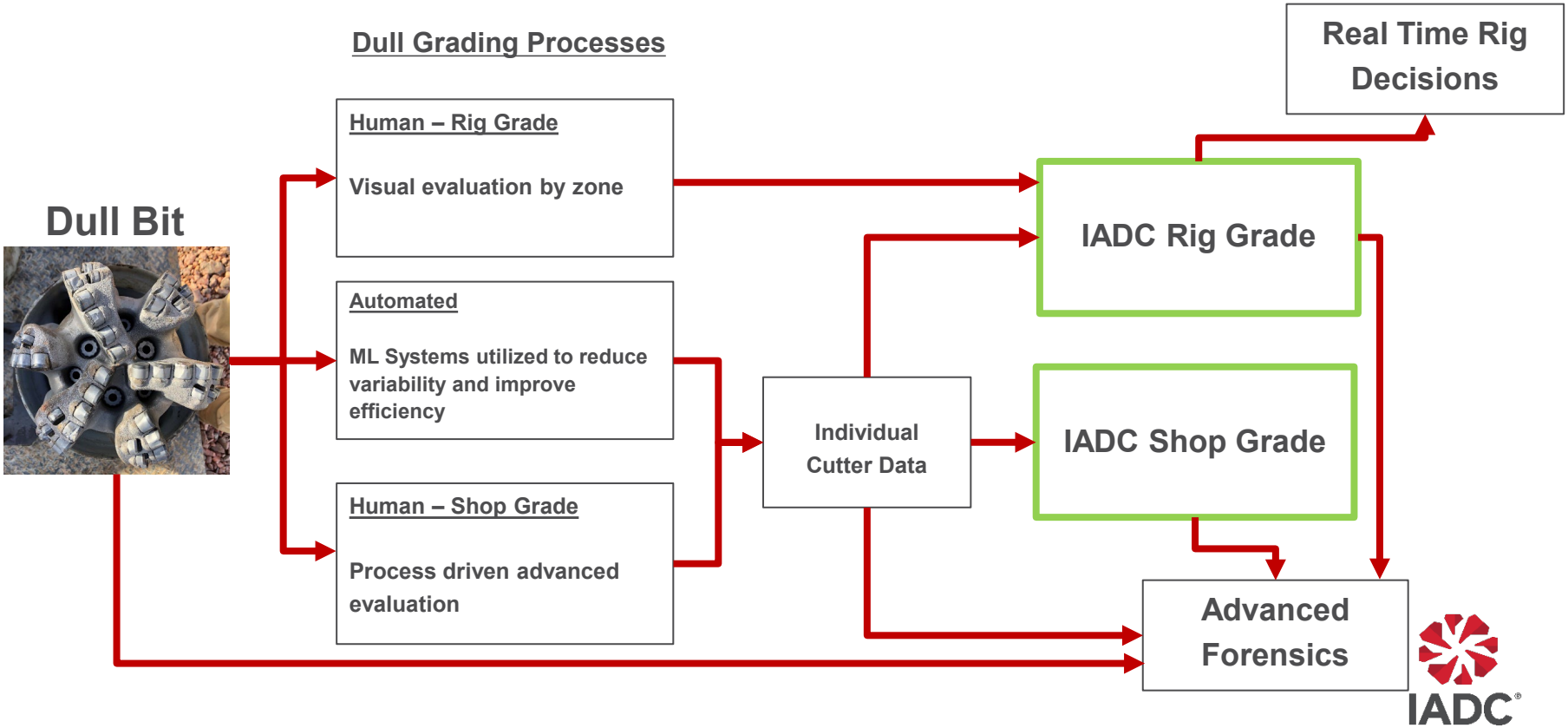
Progress Overview

- SME forum established
  - 17 Meetings to date
  - Attendees 30-50/meeting
- Extensive polling
- Training document drafted
  - Group effort
  - 42 pages of content so far
- Training examples developed



Advanced Dull Grading Process Map



Grading Every Cutter

- Enabling consistent data rich dull grading is key to unlocking advanced bit forensics
  1. Define process for how to grade a single cutter
  2. Grade each cutter on the bit
  3. Summarize the tabular data into a standard format

CUTTING STRUCTURE				B	G	REMARKS	
INNER ROWS	OUTER ROWS	DULL CHAR.	LOCA-TION	BRNG/ SEALS	GAUGE 1/16"	OTHER CHAR.	REASON PULLED

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Blade	Pocket	Bit Zone	% Loss (Area)	Diamond Damage Class	Substrate Damage Class	IADC Loc
1	101	C	0.00%	ND	ERS	I
1	102	C	1.59%	ND	NDS	I
1	103	C	0.00%	ND	NDS	I
1	104	N	1.41%	ND	NDS	O
1	105	S	60.06%	ND	NDS	O
1	106	S	32.48%	ND	NDS	O
1	107	G	97.47%	WC	NDS	O
2	201	N	0.24%	WC	NDS	I
2	202	S	59.83%	WC	NDS	O
2	203	S	24.28%	WC	ERS	O
2	204	G	4.57%	SC	ERS	O
3	301	C	0.00%	SC	ERS	I
3	302	C	0.02%	SC	ERS	I
3	303	N	0.18%	SC	ERS	I
3	304	S	99.85%	SC	ERS	O
3	305	S	12.11%	SC	ERS	O
3	306	G	0.95%	SC	ERS	O
3	307	G	2.00%	SC	ERS	O
4	401	N	1.33%	SC	ERS	I
4	402	S	29.94%	SC	ERS	O
4	403	S	21.07%	SC	ERS	O
4	404	S	98.95%	SC	ERS	O
4	405	G	3.04%	SC	CRS	O
5	501	C	0.33%	SC	CRS	I
5	502	C	0.26%	SC	CRS	I
5	503	N	0.57%	SC	CRS	I
5	504	S	8.12%	SC	CRS	O
5	505	S	32.98%	CC	CRS	O
5	506	S	20.99%	CC	CRS	O
5	507	G	3.98%	CC	CRS	O

2

3

	PDC Cutter Damage			
	Cone	Nose	Shoulder	Gauge
Cutter Damage Severity	0.3	2.2	7.5	3.8
% Diamond Loss	5%	20%	27%	44%
Primary Cutter Damage Char.	ND	WC	SC	BC
Secondary Cutter Damage Char.	ND	SC	BM	TB
Substrate Damage Char.	NDS	NDS	ERS	ERS

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Key Accomplishments

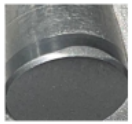
- Universal damage classification scheme established

PDC Cutter Damage Categories:

ND – No Damage
CD – Chamfer Damage
CC – Chipped Cutter
WC – Worn Cutter
SC – Spalled Cutter
BM – Beach marks
IS – Island Spall
BC – Broken Cutter
AB – Axial Break
TB – Tangential Break
DC – Delaminated Cutter
FC – Face Crack
ID – Indeterminate Damage
LC – Lost Cutter

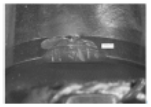
Red Text indicates shop grade only categories

Advanced Cutter Damage Categories – Shop Grade



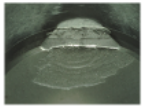
CD – Chamfer Damage

- No Major Damage w/ Rounded Chamfer



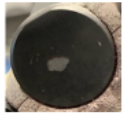
CC – Chipped Cutter

- Wear scar with angular and/or flaking cutting edge



BM – Beach Marks

- Spalling with indications of curved fractures on the face of the diamond

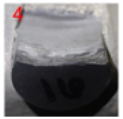


IS – Island Spall

- Spalled Cutter w/Diamond Pull Out. Flaking of the cutter face does not extend to the carbide and some of the face remaining intact, whereas a portion of flaking is surrounding by intact cutter face

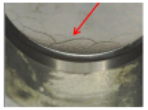
AB – Axial Break

- Diamond loss exposing a portion of the carbide substrate with at least a portion of the diamond fracture plane parallel to the cutter face, but with some cutter face intact



TB – Tangential Break

- Cutter sheared through diamond face through entirety of substrate



FC – Face Crack

- Diamond face has single or multiple cracks that have not propagated to failure

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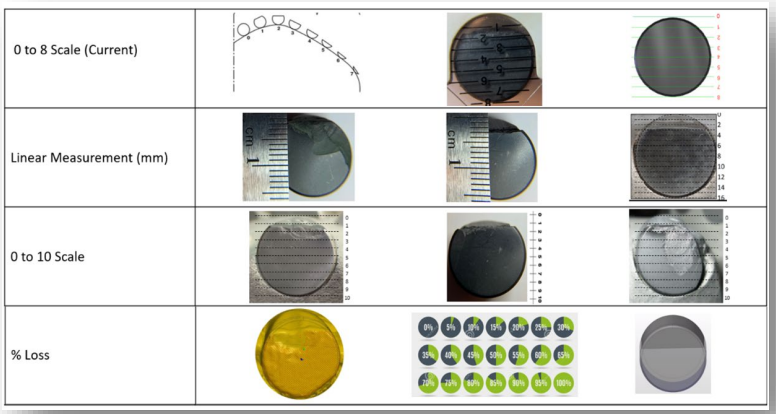
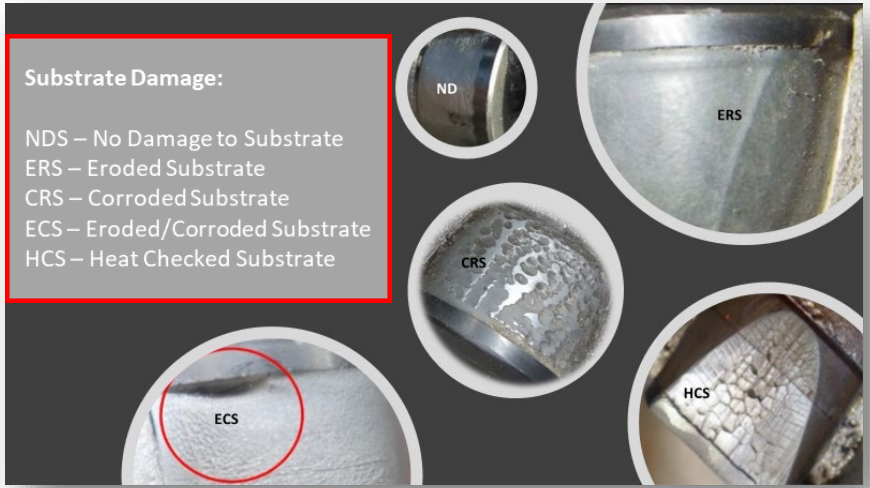
Key Accomplishments - Cont.

- Introduction and standardization of additional measurements
  - Cutter substrate damage classes
  - Severity measurement system
  - Bit zones expanded





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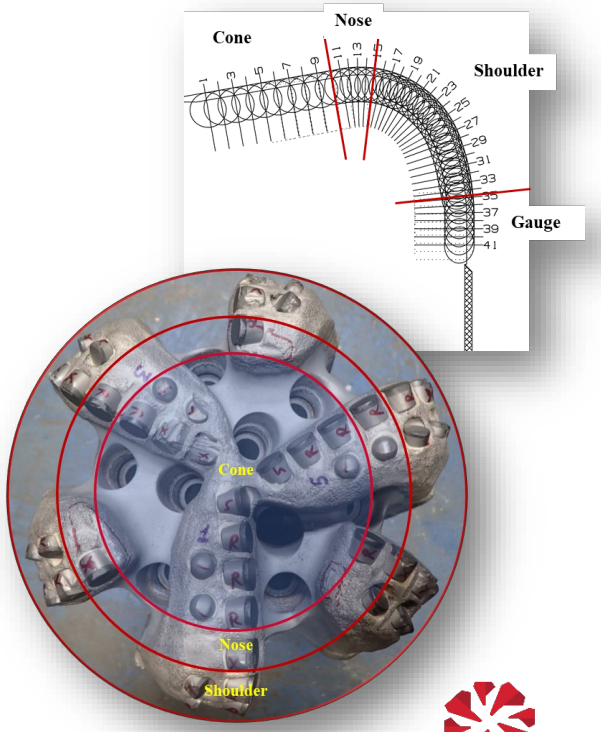
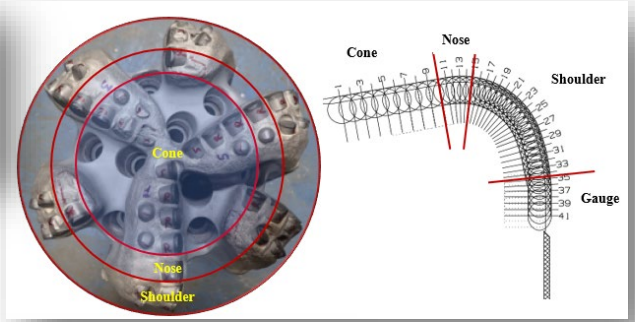
Bit Zones – expanded from Inner / Outer

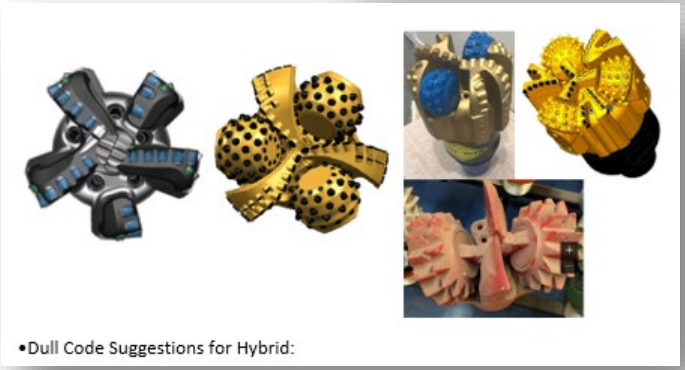
- **Cone:** Cutters at the center of the drill bit, inside of the nose
- **Nose:** The cutter at the highest point of the blade arc (one cutter per blade)
- **Shoulder:** Cutters between the nose and gauge
- **Gauge:** The first cutter aligned with the top of the gauge pad



Additional Considerations - Subgroups

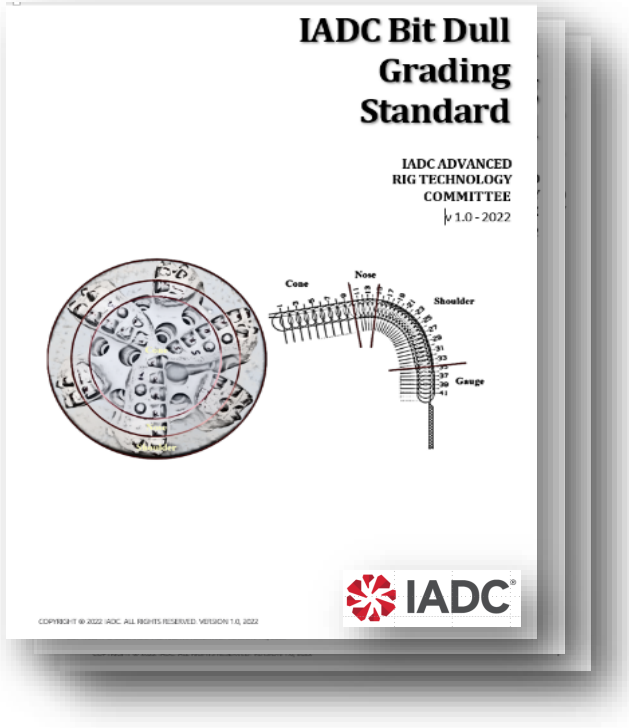
- Drill bit zone definition
- Shaped cutter compatibility
- Impreg/Hybrid bit compatibility
- Core head compatibility
- Roller cone compatibility
- Drill bit damage categories
- Reason pulled
  - (collaboration with BHA team)





Next Steps

- Finalize training examples
  - Develop field test plan
  - Refine coding, fix issues
- Revise paper/instructions
- Develop digital interface (DDR)
- Publish new standard



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On to the BHA Group!

Paul Neil