Digital Fluids Management (DFM)

When Your Best Mud Engineer meets AI/Machine Learning

HUMAN INTELLIGENCE | ARTIFICIAL INTELLIGENCE | COLLABORATIVE INTELLIGENCE

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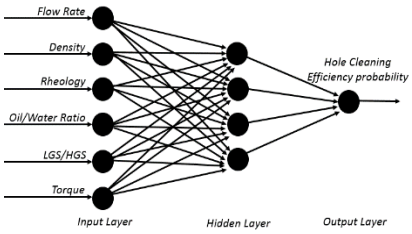

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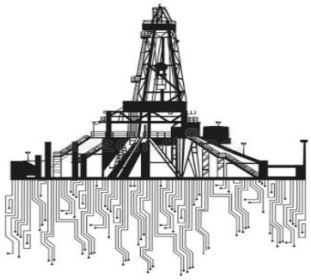

KNOWLEDGE TRANSFER | MACHINE LEARNING | DIGITAL FLUIDS MANAGEMENT

What to expect when your best Mud Engineer meets AI. Your best mud engineers look at the back yard drilling fluids process in its entirety, holistically gathering all available information from the drilling fluids, solids control equipment, mixing system & the waste management process and continually correlating this data back to drilling performance and NPT avoidance. Your best mud engineers are populating a static hydraulics model, concentration sheet, calculating solids control system performance, running dilution economics, and managing the waste stream being generated daily. The expectation is to build a digital twin around what your best mud engineer would do as a process flow.

What digitization & AI will do is enhance the capabilities of your typical mud engineer. A typical mud engineer evaluates mud property trends and performance, utilizes recipe's and concentrations to determine product formulations and expected property responses, analyze the solids impact on the fluid as it pertains to dilution and fluid losses. Digitization will help fill in many of the gaps, as very few mud engineers, if any, evaluates the backyard's performance as pertains to solids removal efficiency vs dilution vs environmental monitoring of the waste streams and how this all impacts drilling performance. This is where software can help fill in the missing pieces to provide our rig crews with enhanced data diagnostics to equip them with the tools they need to make informed decisions.

Recent advancements in AI/machine learning applications allow for what is termed "Collaborative Intelligence" where the subject matter expertise of the Mud Engineer can be combined with the big data processing capability of the AI agents to deliver high frequency decision making analytics that was just not possible until now. It's unreasonable to expect that your mud engineer run a mud check from 6 samples points on the rig each time he checks the condition of the mud system. Instead, we take the routine task of measuring the drilling fluid properties manually and replace it with instrumentation that can deliver a mud check every second from each of the 6 sample points in the process. This creates more time for the mud engineer to do mud engineering rather than mud checking and he can do it all remotely.

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The first steps toward digitizing the process, we need data, lots & lots of data. In the drilling fluids management space, the data that we need must come from real time instrumentation, not from manually entered lab data 1-4 times per day. The real time high frequency data is used to train the AI algorithms to react the same way as your best mud engineer, i.e. what would your best mud engineer do when he needed to proactively manage a developing LGS problem? The mud engineer would review the data set he has available to him and using his experience he would create action plan or work flow that will help mitigate any problems or issues that could be developing. The measurement frequency from the real time data allows us to populate models (work flows) that even your best mud engineer has conventionally been blind to. For example, using material balance algorithms, the real time data will tell us how much rock has been drilled vs how much has been removed from the well in real time. Solids control equipment performance has become a topic of digital twin development, the software will use real time data to automatically adjust the centrifuge parameters based on the programmed specification. Your best mud engineer was never privy to this type of information in real time.

Dozens of mud engineering calculations can be done in real time providing trends to planned vs actual relationships at all times. Depending on what KPI is being monitored, the data will be fed into machine learning algorithms that will weight the best case, worst case & most likely case based on the information being conveyed at the time. This capability to process the real time data accurately will result in early warning indications to common drilling anomalies, provide the driller with actionable data to proactively mitigate problems before they turn into NPT events. For example, monitoring the hole cleaning efficiency using both hydraulics & mass balance algorithms will identify a cuttings bed slowly building that is being caused by an increase in LGS in the system. This LGS increase is impacting the cuttings transport, the PV is increasing, the cuttings bed is growing, the ECD climbing, the pump pressure is increasing, the torque & drag is out of spec. Conventionally, the driller would need to keep track of this dynamic playing out in front of him, then to add insult to injury, the last mud check was 12 hours ago and there is no one looking at the solids control equipment performance. Fortunately, in this new process work flow, the AI algorithms will not only weight the probability of a stuck pipe incident or twist off event but will automatically make solids control equipment adjustments to address the LGS problem. The AI algorithms will also be predicting the probability of a downhole tool failure due to the excessive ultrafine low gravity solids. We need to give our drillers and mud engineers all the tools they need to do their job efficiently, empower them with the right information at the right time, that's Collaborative Intelligence when human expertise is coupled with smart machines.

To digitize the back yard, we must collect the required real time data to drive the software. At minimum, the following sensor requirements are needed:

- Flow rate, density, rheology & OWR going in and out of the well in real time. This data drives the Mass Balance & Hydraulics Algorithms in real time.
- Flow rate, density, OWR and PSD going in & out of the solids control equipment. This data drives the solids control equipment performance and waste management algorithms.
- Flow rate, density, OWR of all dilution volume going to/from the active mud system. This data drives the dilution economics algorithms as well as compositional analysis information about the mud system.
- All real time compositional analysis data will be used to drive an automated digital mix sheet formulation. This deliverable will lead into the development of an automated mud mixing system.

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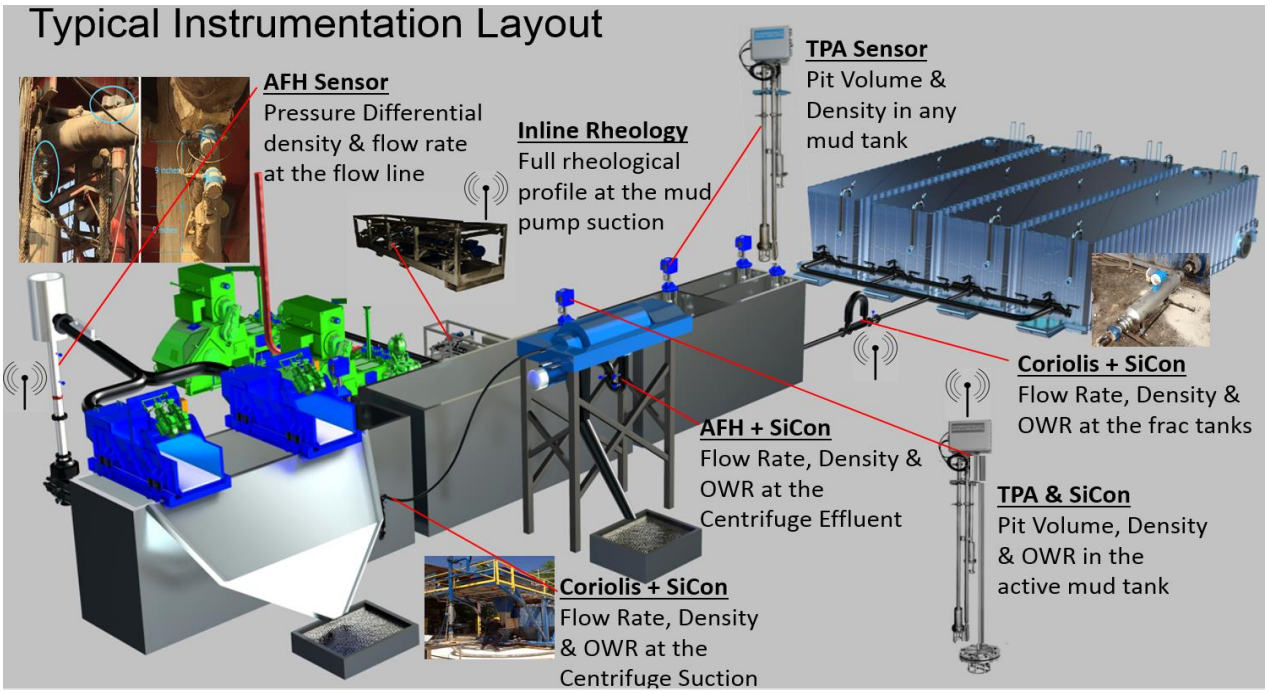

The Four Biggest Challenges in every Well Delivery Process that can be addressed with AI:

Gains & Losses – maintaining control of the well has migrated from the old conventional "nut on a string" to measuring complete mass balance, quantifying gains & losses using delta mass flow data that always confirms what volumetric flow of fluid is exiting the well in real time. Couple the measurement frequency, accuracy & data quality with a machine learning algorithms that studies the data and provides a signature pattern of possible outputs. The AI agent will apply advanced analytics to determine at all times if the data is indicating a kick vs ballooning vs losses. It is time we remove all doubt from the process by measuring flow rate & density in real time.

Cuttings Removal Efficiency from the well – With the invention of better bit technologies nearly every rig is capable of drilling faster than ever before. This increased ROP has brought about a new problem with regards to maintaining adequate wellbore hydraulics to maintain good hole cleaning efficiency. Historically engineers populated static hydraulics models with data that was 6-24 hours old. Now we use real time flow rate, density & rheology data to identify the leading indicators to common NPT events, the software helps maintain a proactive approach to hole cleaning rather than reactive. Advanced mass balance algorithms coupled with hydraulics models will provide a window into the hole cleaning process that will allow for early prediction and subsequently prevention of hole cleaning problems turning into NPT events.

Solids Removal Efficiency/Dilution/Waste Management – We remove massive amounts of drilled cuttings from the well, now we must remove those drilled cuttings from the mud. Quantifying solids control equipment performance has historically been a manual method done using data that

could be 24 hours late depending on how detailed the mud engineer was at collecting his data. Now the sensors and software can perform big data analytics to weight the drilling fluids dilution data against solids control equipment performance and waste management to identify the optimum dilution volume required to deliver the drilling objectives. The sensors will also allow for the automatic adjustment of the solids control equipment parameters to ensure the drilling fluid is maintained at programmed specification.

Well Placement/Directional Control – The well placement process is the holy grail that can make or break a wells profitability. The major advancements in directional drilling hardware & software has led the industry to some major advances in automation. The synergy between directional drilling AI/machine learning software and drilling fluids management has lead us to a place where true drilling automation can now be achieved. A totally integrated, holistically managed approach is the gap that can now be filled but marrying the 2 together. Historically the well delivery process has been largely compartmentalized, several entities working through their own individual work flows, not communicating to the client what is in the best interest of the well. With digitization/automation the entire drilling process becomes transparent, all entities working in unison to deliver the best product.

Conclusion: Our industry is right on the cusp of making radical change in the well delivery process. With the integration of advanced machine learning software, new sophisticated measuring solutions and a real necessity to reduce costs, we are positioned perfectly to deliver on that requirement. In this new work flow, the focus will initially be on improved efficiencies, reduce costs of consumables, mitigate invisible lost time and remove NPT from our operations. The long term goal of digitization/automation will be to deliver consistency to our well delivery process and the added bonus to all of our initiatives is an optimum producing well.

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