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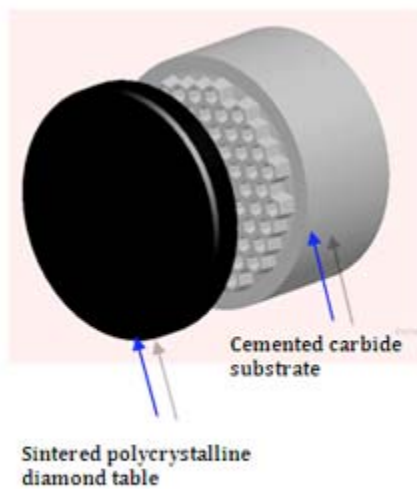
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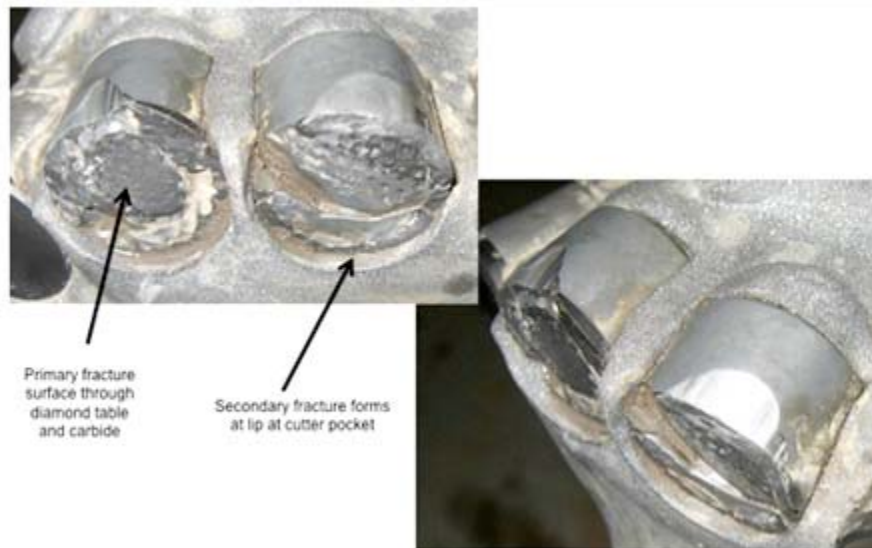
## Seven Steps to Reducing Failure and Cycle Time

US Synthetic manufactures high quality polycrystalline diamond compacts (PDCs) used in drilling for oil and natural gas. PDCs are manufactured with a sintering process that fuses premium saw-grade industrial diamond crystals under a heat of approximately 3,000 degrees Fahrenheit and a pressure of about 1 million psi without actually melting them. During the process, the fused diamonds are bonded to a tungsten carbide substrate. These PDC's have been around since the mid-1970s, yet manufacturers continue to experience some common problems, one being table breakage or delamination, the separation of the diamond table from the substrate.

US Synthetic's failure rates have been small and customer satisfaction is high, but some customers have reported failures on small numbers of cutters on drill bits while all of the other cutters remain intact. While this doesn't make the bit useless, it slows down the penetration and leads to an eventual loss of drilling time for costly tool withdrawal and replacement.

Resolution of this problem was turned over to the engineering team. In addition to the PDC cutter failures facing the team, the manufacturing team was looking for a way to reduce the time required to make the cutters. The reason for the cutter failures needed to be determined of frequency and manufacturing time were to be reduced.



**Figure 1.** PDC (left) Drill bit (right)**Figure 2.** Diamond table delamination observed on a dull drill bit. Primary and secondary fractures exist.

Traditionally, such an effort to reduce or eliminate the cutter failures would amount to a trial and error affair, beginning with replication of whatever was taking place when the failures happened. In this case, it would require a device in the lab to drill through rock with mounted PDCs. Next, a list of factors which might be the cause would be assembled, PDCs would be made to the new specifications and tested. For example, if temperature was suspected as a factor that could have caused the failures, new PDCs would be made using either a higher or lower temperature, then tested in the lab. This would have to be repeated at various temperatures both higher and lower than the original. If no significant change in the failure rate was noted, the process would have to be repeated with another factor—heat-up time, for example. Likely, the process would go on indefinitely using temperature and heat-up time as well as other factors before the cause of the failures could finally be determined. At the same time, a parallel effort would be started by the manufacturing team to reduce cycle time, even though many of the variables would overlap. This old process is, of course, very time-consuming, labor-intensive, and very expensive. US Synthetic needed a different path.

Objective Design of Experiments [2] (DOE), in Bellingham, Washington, trains engineers and scientists to use computers instead of the old "one variable at a time" laboratory experiments with a strategy that allows the input of multiple variables and result predictions for a great many experiments without having to actually perform them. By choosing the best resulting prediction, only a few "in-the-lab" experiments are necessary. This process makes reaching the desired results faster, easier, and, best of all for the company's bottom line, less costly. This sounded good to US Synthetic, so they contacted

Objective DOE and arranged for the training.

The research team at US Synthetic used the following seven steps in the Objective DOE strategy to set up and perform their experiments.

*Step One* is to ask the right question.

The engineering team asked how it could reduce cutter failure a minimum of 5 percent. The manufacturing team asked how it could reduce manufacturing time without affecting quality in a parallel effort. It's important to note the two different efforts as they certainly overlapped.

*Step Two* is to choose a model.

The four most important factors in the experiment design were surface condition, heat-up time, cool-down time, and decompression time. A customized polynomial model was chosen, allowing the prediction of results for experiments that have never been run.

*Step Three* is to choose an experimental design.

Since a custom model was chosen, a computer program, Gossett, was used to create a customized experiment design. US Synthetic got exactly the design plan they needed.

*Step Four* is to collect the data.

The most important responses in the experiment were "cutting distance to delamination" and "cycle time for manufacturing." Each experiment in the design was run and these responses were measured.

*Step Five* is to analyze the data.

Analysis of the data gave the team a 95-percent confidence that heat-up and the interaction between heat-up and cool-down were statistically significant.



**Figure 3.** Granite rock cutting experiments are conducted to measure cutting distance to delamination failure.

*Step Six* is to test the model.

The best combination of factors for reducing delamination, the "sweet spot," predicted by the model was tested. This condition increased cycle time. The research team went back to the model and chose the sweet spot to reduce delamination failures and shorten cycle time. At this stage, the research and manufacturing goals overlapped. Both sweet spots showed an improvement, so the spot with the shortest cycle time was implemented. At the time of this writing, the improvement in the field is being quantified. Quantifying improvements such as these are costly and time consuming. However, a US Synthetic customer has noticed the improvement in applications where this failure was common.

*Step Seven* is to celebrate success.

The teams celebrated completion of the first phase of their task with a victory lunch. They will continue to work on quantifying the failure rate and reducing it even further by using design of experiments, which will ensure that their work will be better, faster, easier and, most important, much more cost effective.

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[1] <http://www.ussynthetic.com>

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