A Nano-Die® Experiment that Every Cable Manufacturer Should Perform

It seems like a long time ago that PCD dies were found to be better than tungsten-carbide dies in cable stranding and compacting operations. Things don't change overnight and this must be the reason why so many cable manufacturers are still using tungsten-carbide dies at diameters below Ø37mm where PCD dies could be supplied. Admittedly, PCD dies are extremely expensive by comparison with tungsten-carbide dies.

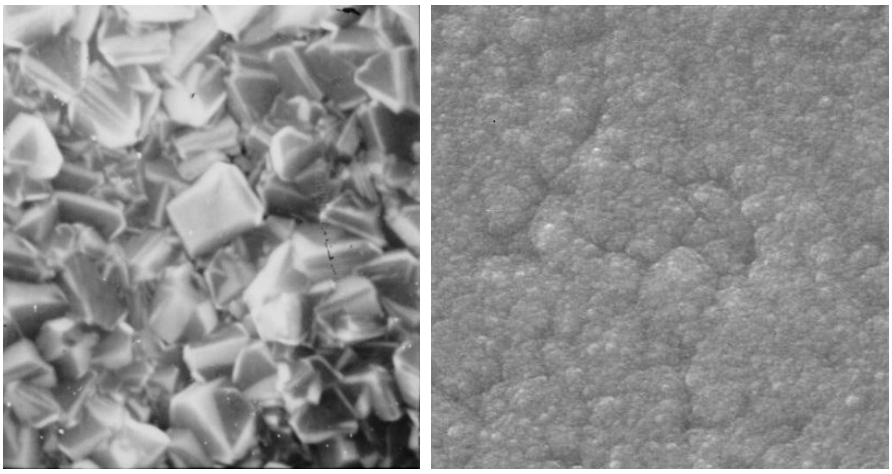
Now there is a new type of compacting die called a Nano-Die which is significantly better than both of the well known types. But a Nano-Die costs <u>3 to 6 times less</u> than the corresponding PCD die and it is available up to Ø60.0mm (Ø2.3" approx).

What is meant by better? Traditionally, users have looked at price compared with die life. Price/Performance is an easy comparison to make, but it overlooks a factor which is so important that the cost of the die becomes insignificant. Some dies force the cable manufacturer to use more Copper and Aluminium than other dies. The cost of this additional raw material is much more than the cost of ANY dies, so the cost of the dies is no longer important. This explains how PCD dies managed to replace tungsten-carbide dies in many cable plants, despite the fact that the PCD dies cost 20 or 30 times more.

The additional Copper or Aluminium required when tungsten-carbide dies are used for cable compacting is in two categories. The most obvious one is due to tungsten-carbide dies quickly wearing larger. If a cable manufacturer typically permits a Ø18.0mm die to wear to Ø18.1mm before it is replaced, the cost in additional raw material is roughly 0.5%. This wastage of 0.5% of total Copper or Aluminium is saved immediately by changing to PCD dies or to Nano-Dies, both of which hold diameter tolerance +0 for a very long time. Nano-Dies in particular hold a +0 tolerance throughout their entire working life, which might be 500-800km of cable compacted.

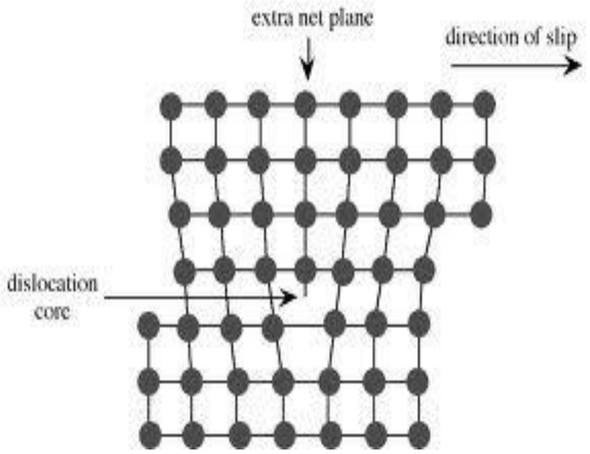
Comparing tungsten-carbide dies with Nano-Dies, users have consistently and conservatively reported Copper and Aluminium savings of 2% to 3%. It is easy to explain 0.5% exactly as per the above paragraph, but where are these additional savings of 1.5% to 2.5% of total Copper and Aluminium usage coming from?

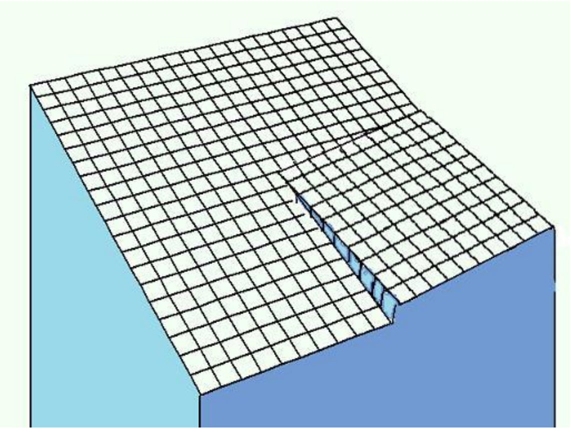
Contrasting the difference between the surface of a PCD die (left) and a Nano-Die (right) 4,000 x Magnification



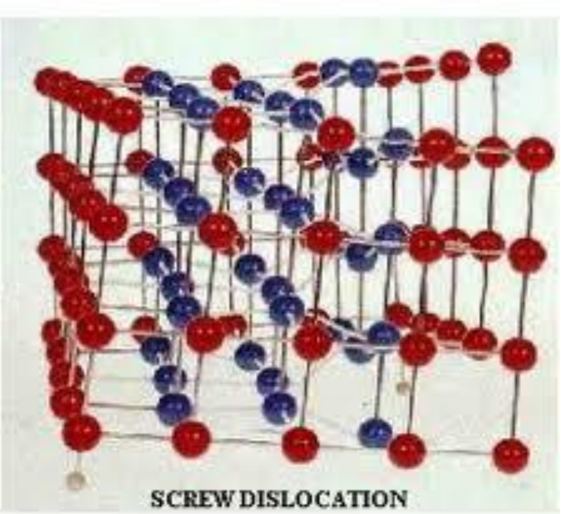
The answer is found in the smooth surface and extremely low friction characteristic of Nano-Dies. It is a subtle point. Nano-Dies have extremely low friction, hence less energy is required to complete a compacting or stranding process and less damage is done to the conductors in the process of being compacted. The damage which otherwise is done to the microstructure of the metal is in the form of dislocations in the crystal structure. The subject of dislocations is a major field of study within Physics and

Illustrating commonly occurring Crystal Dislocation types. Lower friction in Nano-Dies means fewer of these faults. And that gives a better result for electrical resistance (Nano-Dies = Low Electrical Resistance).





Metallurgy, but the bottom line is that every time a dislocation occurs, the electrical resistance of the metal increases slightly, due to the free electrons having slightly less freedom of movement than before. Nobody has yet developed a formula which can be used accurately to predict how much the electrical resistance increases for a given deformation, but some pictures of dislocations are available which clearly show the general idea.



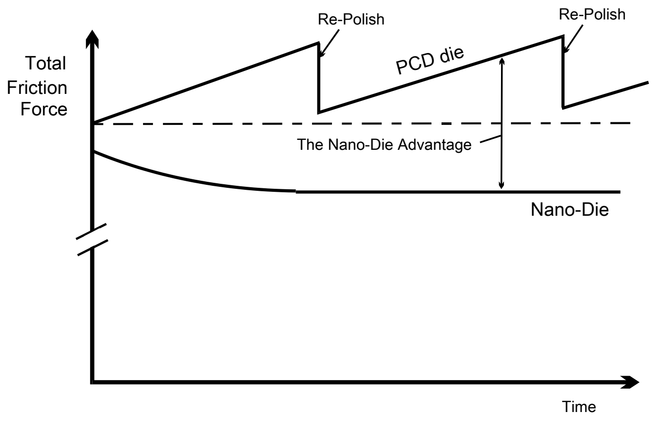
Hence, if the number of dislocations can be minimized by means of Nano-Dies and their very low friction surface, then the final electrical resistance of the cable will be lower. Cables have to pass an Electrical Resistance Test and they pass this test too easily if the only thing you do is change to using Nano-Dies. So cable manufacturers lighten the conductors by an appropriate amount (i.e. slightly reduce the diameters of the individual conductors), thereby increasing the electrical resistance again to where it started, and they save 1.5% to 2.5% of Copper and Aluminium by this action (compared with TC dies) or 0.5% 1.5% (compared with PCD dies).

Are these savings worth going after? An increasing number of cable manufacturers think so. Typical Copper usage varies widely, but we are aware of a plant using Copper to the value of

$54,000,000 every year to meet the needs of a single 300mm² cable product. Usage in excess of $10,000,000 per month is not uncommon in a modern cable plant.

Comparison between Nano-Dies and PCD Dies:

Figure 1 - Die Friction Characteristics



The common factor between Nano-Dies and PCD dies is that both types hold a +0 tolerance for a long time. Hence both types are capable of making the obvious raw material savings compared with tungsten-carbide dies which quickly go out of tolerance.

The differences are indicated in Figure 1. A PCD die surface degrades with time, hence it is necessary periodically to re-polish the die. Most, but not all of the original surface quality can be regained in this way.

By comparison, the Nano-Die starts with a better surface quality (lower friction) than the PCD die and, remarkably, the surface quality of the Nano-Die actually improves over time. The Nano-Die is the only die in the world today that gets better as it is used. The full explanation of this remarkable characteristic will be left for a future article. With reference to Figure 1, the Nano-Die has lower friction than the PCD die throughout its life and this is what makes the additional Copper and Aluminium savings possible when Nano-Dies are used.

The Experiment:

The experiment that every cable manufacturer should perform is this:

1. Measure the electrical resistance of a particular cable using your present dies.
2. Replace the compacting and stranding dies with Nano-Dies of <u>identical diameters to the original dies</u>. Leave everything else the same.
3. Measure the electrical resistance again.
4. Draw your own conclusions.

Doug Thornton
Nano-Diamond America, Inc.
2025 Woodbrook Court
Charlottesville, VA 22901 U.S.A.
www.nano-die.com