Sawsimul

Sawsimul is a mathematical model, which has been developed in order to simulate sawing with circular diamond blades.

WHAT ARE THE ADVANTAGES OF A MODEL FOR DIAMOND SAWS?

- **SAVINGS** ON EXPENSIVE TEST ROOMS OR FIELD TESTS
- BETTER PARAMETERS **OPTIMISATION** (diamond, bond, geometry, machine, sawing conditions,…)
- MODE **ACCURATE** RESULTS (provided the model is reliable in this range)
- **TRAINING** OF FUTURE EXPERTS

DIAMOND TOOLS CAN NOW BE TESTED VIA COMPUTER PROGRAMS!!!

A saw blade simulator has been developed by Custodiam, thanks to several years of real life tests' observations. In most cases, the parameters for a specific application of a diamond tool are still chosen according to experience and following an individual approach. Although general rules exist, no specific expert system has been able to determine what are the best conditions for optimum efficiency. Moreover, real life tests are expensive, inaccurate and require lengthy response time. Therefore, an attempt, hereafter described, has been made in order to find a better way to get a cheap, accurate and quick response.

TYPES OF MODELS
Computer models for diamond tools can be built in different ways. It is possible to set up a huge ***database*** detailing all the case histories that can be encountered. With an appropriate and advanced query system, a record similar to a current problem could be identified and solved by analogy. However, this would not be helpful faced with new developments.

Another model type, which could be called ***multiple regression***, can be based on a system of equations using all known parameters. In the case of a linear model, it would give the following:

Tool performance =	K1 x diamond performance + K2 x tool performance + K3 x machine performance + K4 x operator performance
where diamond performance =	k11 x particle size + k12 x average shape factor + k13 x toughness index + k14 x wear resistance + k15 thermal stability + etc…

and the same for tool, machine and operator performance. Real life is of course far from being linear, but around some equilibrium conditions, the error of the linear approach is not too important. During the 1970's and 1980's, such linear model has been successfully used for simple diamond evaluation. But from the moment the available synthetic diamond range has been extended to higher and lower grades, the linear model had to deal with more and more exceptions. Although more complex to develop, a non-linear multiple regression model obviously shows better performance. Such type has been approved for diamond evaluation for example during the 1980's and 1990's. Another type of model, the macroscopic one, can be developed based on basic geometrical considerations of diamond tools behavior. Only a few equations have been published (see references 1 and 2).

These theories have led to interesting concepts like the average chip cross-section (see references 3 and 4).

The weakness of macroscopic geometrical models lies in the limited role of the abrasive. In most cases, it seems to also work without diamonds!

A ***microscopic model***, like Sawsimul, on the contrary, based on what happens to diamonds, has given an important role to the properties of the abrasive itself (see reference 5).

The basic algorithm is the monitoring of each diamond particle during its life. Of course, nothing bad can happen to a diamond before emerging from the matrix. As soon as a particle shows up, it starts to wear, at an ever-increasing rate in case of harsh working conditions and poor wear resistance of the abrasive.

When the particle protrusion is sufficiently important, more sizeable damage starts to occur. In the model, each diamond particle has its own resistance to destruction. The impact resistance of the free diamond grits is used to calculate an initial value for each individual grit. The impact resistance is further corrected considering thermal damage during sintering. During the sawing process, this resistance will further decrease due to shocks occurring when in contact with the work piece and the abrasive environment. On the other hand, the forces on each working point can be computed from the working conditions (see macroscopic model). When comparing these forces with particle resistance, the program decides whether the abrasive breaks or not. If yes, the diamond characteristics help to decide whether there will be another chance for this particle to work again later (as noticed experimentally under reference 6) or it will be totally crushed (see flowchart, Fig.1). If not, it wears a little and will survive until the next shock during the same or the next revolution, where it will be submitted to the same tests, using the protrusion ranges for each process.

FLOW CHART FOR DIAMOND EVOLUTION

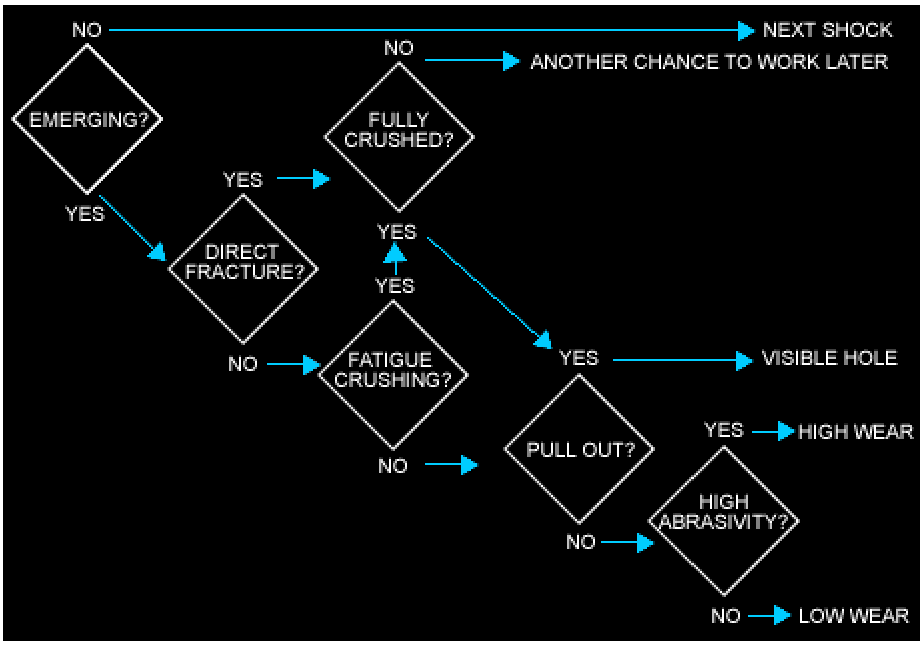

Figure 1

Depending on protrusion, bond characteristics and particle shape, another disaster may occur: the pull out. In such case too, a simple comparison with a threshold is decisive, i.e. to see if these forces are high enough for pull out.

When building such a microscopic model, the bond wear has also to be taken into consideration.

Sawsimul program is a Monte-Carlo type simulation. This means, for example, that for a given toughness index and size range of particles, individual grit properties are generated according to a statistical distribution of toughness indexes and sizes. The same mechanism is applied for generating particle positions in tool and stress conditions which they have to face.

Considering the fact that many calculations have to be made for each working particle, at each shock or at least at each blade revolution, it is now obvious that computer time is becoming a factor to be taken into account, even with high-speed computers.

At this point, most models are considered to be mere approximations. An infinitesimal analysis would certainly be preferred, but it is not feasible due to greater complexity and considerable program execution time.

SO WHAT?

There has to be a compromise between complexity, time and accuracy. Each model type presenting some advantages, it could be interesting to take the best of each and mix them. The final choice could be described as a blending of the multiple regression, the macroscopic and the microscopic models, without use of a database except for simulator testing. Such a complex model has been in use since 1991, giving already satisfactory results in stone and concrete sawing.

An important question is: 'when is such simulator reliable?'. Our reliability criterion is that it should fit real life, within experimental error margins.

The program output is compared with a database of accurate measurements. The simulation program is being improved continuously and each new release is evaluated against the complete database. The input for a simulation is made through three input screens. Help windows make it more user-friendly by suggesting values for each input parameter.

Figure 2

Figure 3

During the computer run, the behavior of the tool and of the abrasive can be followed on the screen. In figures 3 and 4, two steps of the same simulation can be observed. A symbolic representation of the blade section is outlined on the left of the screen. On figure 4, the yield of the saw can be read on a green background (on top: 1.21 m²/ct). This information was not available on figure 3 because the wear rate was not stable yet. The bar chart allows us to follow the relative importance of the different wear mechanisms. Some conclusions can already be drawn by comparing figures 3 and 4: we notice that 45 % of undamaged particles (under the word 'Emerg.') drop to 32 %, the percentage of polished increases (from 2 to 3), 18% in a state of first fracture decrease to 12 %, 9 % have earlier been fractured twice, etc…, the percentage of fully crushed remains 4, 11 % were at first pulled out (visible hole), to finally reach 33 %. Non visible states can also be known e.g. non-emergent or pulled out for which holes are no longer visible (respectively 'Matrix' and 'Disapp.' on the screen).

By pressing specific keys, sawing conditions can be changed and reports obtained.

WHAT IS THE BENEFIT?

Such simulator provides accurate information, which would otherwise not be available, like power loss due to various types of friction, abnormally high temperature, conditions for pull out, reasons for inefficiency, forces, active cross-section, individual diamonds history, etc….

Tool performance can be enhanced by optimizing each parameter of the sawing process. In particular, each diamond property can be evaluated, developing a custom-made abrasive for each specific case. In order to facilitate this optimization, the computer program can also simulate a range of values for a certain number of parameters.

In conclusion, a sawing simulator means major savings in time and money for further developments. It provides accurate results for real optimization. And last but not least, it is a valuable tool for training future experts.

For more information, please send a fax to Custodiam, +32 (0) 2 370 64 99

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RELIABILITY OF THE "SAWSIMUL" MODEL

This table is an example illustrating the correlation coefficient of Sawsimul model's results and real life observations of Circular Granite Sawing.

MEDIUM CORRELATION		GOOD CORRELATION	
		BLADE LIFE	0.80
POWER	0.71	RATIO LIFE/POWER (QUALITY INDEX)	0.92
		POLISHED DIAM. %	0.88
FRACTURED DIAM.%	0.85		
CRUSHED DIAM.%	0.77	FRACTURED + CRUSHED DIAM.% (TOGETHER)	0.88
PULL OUT DIAM.%	0.38	LIFE / DIAM.CHARACT. (PERFORMANCE INDEX)	0.94
		LIFE / SAWING CHARACT. (VARIOUS FEED+DEPTH OF CUT AT CONSTANT STOCK REMOVAL RATE)	0.74