REVOLUTION IN DIAMOND MANUFACTURING

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Abstract

This paper examines the historical developments in diamond beneficiation technology and the impacts on the industry. The art of diamond beneficiation has given way to the application of scientific process, but at considerable capital expenditure. The shift in beneficiation methodologies has been disruptive to the traditional skills set of the industry, but evolutionary change continues and has been beneficial to the quality of the final product.

1 Introduction

The scope of this presentation is the recent evolution of diamond processing, starting from the planning and study of the rough, the sawing, the polishing and the quality control of the polished diamond. An additional subject will be the revision of the standards for grading polished diamonds.

2 Discussion

2.1 Why did these changes happen recently?
The longer we wait to take evolutionary paths the more certain it is that we will be required to take a revolutionary path.

2.2 Why was there a lack of motivation for change in the past?
Verification of the process quality wasn't possible. Everybody believed current practice to be the best. Subcontractors were under pressure to obtain high yield but production speed was more important. The benefit of investment in technology to obtain higher yield didn't flow back to the subcontractor

Low investment however was and is still, odd for such a high value raw material. The Gold price at the moment is 1060 $ /ounce that is about 32 $ / gram. A 5 ct polished diamond D/IF is around 100.000 $/ct or roughly 500.000 $ for 1 gram of polished diamond.

2.3 How low was the global investment in diamond technology?
The global annual production for the diamond business is around $12,5 Billion. Manufacturers worldwide debt for financing their transactions is around $11 billion. Yearly investment purely in technology in the manufacturing process is less than 1%,that is around $100 million. The global bike industry worth around $60 Billion invested in new technology over 15 %.

2.4 Why was investment originally so low and why did it suddenly become more important than before to invest?

Traditionally the sight holders system didn't motivate their companies because margins remained high with small investment. De Beers invested in R&D in their center in Maidenhead, but the results didn't flow to the manufactures. Gradually the rough producers increased the rough prices each time some breakthrough innovations added new extra value to the rough, confronting the manufacturer with shrinking margins. The organization of rough tender selling opened new opportunities for the mining companies but created extra challenges for the manufactures.

2.5 What caused technology to become much more important?

Grading laboratories measure the proportions with a much higher reproducibility. Grading rules for polished diamonds were revised and led to more stringent quality tolerances. Polished prices adapted directly to the more severe limitations. A diamond falling in a lower grade had important price implications for the manufacturer. Internet sales grow exponentially each year and together the product information. Polished prices can be easily compared. Off categories are very difficult to sell or at marginal prices.

2.6 What happened in particular with the production technology?

2.6.1 Measurement of rough and rough planning

Sir Ernest Oppenheimer, the architect of the modern rough pricing and distribution system, once remarked that he would challenge anyone claiming they could determine the exact value of a single rough stone. At best, one can value within a 5 percent margin. Therefore, he said, trade must take place through lager parcels as the individual errors would then balance out to correct averages.

Indeed, 30 years ago rough was bought with no more than an experienced eye and a 10 X magnification loupe. Today buyers are using a microscope, a color grading machine and at least a pocket calculator or a PC. But buying single rough diamonds remained, until today, a speculative business.

A new development is that of optical scanners, which are becoming more compact and portable and can scan with laser mapping. The outside geometry of the rough diamond can then be converted into an accurate virtual 3D model. The inclusions can only be allocated after making windows on the rough diamond.

The technology to map inclusions accurately and automatically in a rough diamond is however not far away anymore. Recently new technologies have been introduced for the evaluation of rough before making windows, such as immersion technology, x-ray tomography and optical coherence tomography. All these techniques are close to revealing the secrets of an untouched rough diamond. It is unnecessary to comment on what the impact will be for the whole diamond pipeline from mining company and government of the producing country, but in particular when the rough can be sold with a precise description of the value, in spite of the historical quotations of Sir Ernest Oppenheimer.

When a complete and accurate 3D map with inclusion allocation is constructed, generic algorithms are launched to calculate the solution with the best value. These generic algorithms improve rapidly like the chess algorithms did, and soon a classic expert will not be able to compete with these calculations. This method takes into account: color, clarity, shape and prices of the polished pieces. The final solution can then be accurately transferred in the scanner onto the real diamond by laser marking.

This way of planning in combination with precise processing has many important advantages that will increase the yield on three different levels. Firstly, gathering the "key weights" implements that the system will recalculated, if possible a result of e.g. 4.85 ct and 5.30 ct may be recalculated into two diamonds of 5.05 ct because the latter have a much higher total value.

Secondly the manufacturer doesn't need to keep as much reserve as in the classic approach of the rough planning, where a relative large reserve is needed on the sawing plane of the main stone. This usually means that the secondary stones are traditionally much smaller due to this need for a reserve.

The third level is related to the optimization of a rough piece divided in more than two parts. In the classic approach, the main stone is cut off first, and then afterwards one is looking at the possibilities to divide it further. In the new approach one can take an overview directly from the beginning, evaluate all possible ways, choose the most profitable direction and then process the rough without additional calculations, in a much shorter processing time, increasing efficiency dramatically.

New for the industry and introduced in 2004 is the simulation software Diamcalc. Only one company is producing such software, Octonus. This allows simulation in an astonishing way; the brilliance of all classic shapes with all parameters and to calculate not only the weight or the dimensions but all angles and the total facet arrangement in 3D. The program allows one to evaluate the real appearance of any traditional shape or preview how a new own designed shape will appear before the real diamond is touched. Even the accurate simulation of the color saturation of any cut can be displayed when the visible absorption spectrum is feed into the program.

All this measurement equipment became a must for any manufacturer and as a consequence became the concept of a modern polishing factory multiple times more expensive than 10 to 15 years ago.

2.6.2 Cleaving

Cleaving was originally the only way to divide a diamond crystal in two cleaner pieces with a higher value than a single bigger piece with inclusions. This technique disappeared when classic sawing became more productive.

2.6.3 Classic sawing

Sawing was invented at the beginning of the 1900s and enabled the division ofa diamond in a safer way than cleaving. Although the process remained complex and triggered uncertain parameters. The technique was very popular in the Belgium industry. In 1974 De Beers opened a production plant for classic sawing and a research plant for the automation of the sawing process. After 20 years De Beers closed the sawing plant. Sawing was completely automated and the cost was cut by a factor 6. But in low labor countries like Thailand the cost for classic sawing was still lower by a factor of ten.

2.6.4 Laser sawing

Around 1985 infra red lasers were introduced for diamond sawing. Nobody could believe at that time that the laser process would become commercially viable. The weight loss was too high, around 5 % against 2 to 3 % for classic sawing.

The process was not stable, causing a high danger for cracks. The installation had a much higher cost than a classic sawing bank. The enormous advantage was the possibility to cut a rough piece in any direction.

It took until 1995 before a commercial laser installation was available with good stability and a weight loss of only 2 to 3%.

The training time for a classic sawyer to become productive was around 1 to 2 years. An operator for a laser sawing machine can be trained in a few weeks.

The skills to study the rough to detect the sawing plane for drawing were not necessary anymore. With the recent introduction of the green laser (frequencies doubled IR laser) decreased the weight loss to 1 % and in some cases even less than 1 %. The danger for cracks became minimal, the speed around four to five times faster than the IR laser.

Numeric control of the cutting process made shaping possible for any type of fancy cuts.

The last improvement is the direct coupling between the optimized rough planning and the laser machine keeping accurate coordinates in the same holder as well as for measurement in the scanning equipment as on the laser cutting machine. This precluded human mistakes in transferring a calculated solution on the real diamond.

2.6.5 Bruting

Bruting was the only way to give a smooth curved surface on a diamond. It was primarily only used to make round brilliants round (cylindrical).

The technique was quiet brutal, the diamond to brute was fixed and centered on a bruting machine, rotating at a high speed (2,000 rpm) while a sharp diamond edge was pushed onto to it. Cracks,small feather and mistakes during the manual process were very common. This technology lasted for many years and it became an art to do the job very well. Afterwards different types of machines came onto the market, with pre-centering and bruting two diamonds against each other.

Around 1980 a new type of bruting was invented in Russia. The sharp edge diamond was replaced by a diamond wheel impregnated with fine diamond powder. The process was called electrolytic bruting, because it was a wet process, stabilized by an electric current. The result was a much smoother surface quality. Afterwards several improvements from different producing countries like Israel and Belgium developed this type of semi-automatic bruting equipment.

However the combination of a top quality surface and the possibility to stop the process accurately and automatically on a preset diameter has only been achieved very recently. A brand new development of a "bruting" machine is in fact an automated girdle faceting machine that allows the production of any shape. New in this technology is the direct coupling between the calculated solution on the computer and the accurate transfer on the same holder on the bruting machine.

It is unnecessary to explain that the new development has two sides. Mistakes are excluded and productivity increased but the experienced bruter lost his job completely and a graduated technician (operator) is taking over this role.

2.6.6 Polishing

Beginning last century a manual solder dop was still in use to polish a diamond. It is still a great mystery as to how a polisher could achieve such a good quality in a primitive tool like this. It was necessary to replace the diamond eight times in the solder dop only to polish the crown side of a round brilliant.

Around 1935 the first mechanical dop was invented and until now still in use in a more sophisticated format. The manual polishing was originally done on an indirect driven polishing wheel, the so called mills with belt, had many transmission and leveling problems.

About 20 year ago a British company, Coburn, launched direct driven mills onto the market. The polishing wheels could be directly mounted on the motor axis. These mills can be easily leveled and subsequently all semi-automatic polishing machines are equipped with this type of construction.

Around 1998 the first semi-automatic blocking machine (dry system) was launched on the market. The Belgian technical research center, WTOCD, was one of the first with an accurate presetting of the depth of the facets and automatic grain seeking system. This particular machine is still very reliable can typically put four dops on one polishing wheel. Apart of the accurate control of the direction of each facet, the can machine produce an accurate preset depth eight crown or eight pavilion facets of a round brilliant.

We can most probably expect the introduction of semi-automatic blocking machines next year, based on a wet system (referring to the bruting technology). This technology will no longer be grain dependent. These machines will be directly coupled with the calculated solutions form the scanning equipment and will be able to achieve a much higher accuracy in an adaptive way by counter coupling of the achieved result with the calculated data. This technology will not only shake the industry but will also open new possibilities like the polishing of models very accurately according to a primary simulated models.

3 The evolution of the quality control of polished diamonds.

The introduction of accurate optical scanning technology for polished diamonds has already mentioned. This created a chain reaction effect on the production process. It is clear that this technology shifted the grading process itself heavily. The increase of the accuracy of measurement and improvements in the grading techniques led to a more consistent grading. The scans become so accurate that they can be used as unique fingerprints.

The proportion measurement becomes accurate to 0.1 % and as a result with a much higher reproducibility than before, preventing nearly any debate.

The construction of an accurate 3D model opens the way to automatic grading of the geometry or the symmetry; all deviations could be detected much easier and led to more consistent grading. Even special high demanding finishing of the brilliandering, like hearts and arrows, can be graded automatically in a similar manner to the certificates department of HRD which has been doing this for nearly two years. The 3D model enables the calculation of repolishing reports for improving the clarity or for improving the cut of the polished stone.

With the right algorithms, it is also possible to automate inclusion measurement and automated clarity grading.

4 The evolution and revision of the standards for grading polished diamonds.

This timeline started at earliest 1953. At that time diamond grading was uncommon and nearly all polished was sold without certification.

During the mid seventies several initiatives started in Antwerp to set up certification laboratories, for example: HRD, IGI, EGL and others. The High Diamond Council took significant effort to base their grading on internationally agreed standards which led to the International Diamond Council for grading polished diamonds or IDC-rules. The main goal was the creation of an objective and scientifically based grading procedure with strict anonymity between grader and owner.

HRD became the first ISO accredited laboratory in 1996. The ISO accreditation means working according to very stringent international standards.

The IDC-rules were approved by IDMA and the WFDB at the world congress in Tel Aviv in 1978. The IDC-rules were slightly revised in 1990 and most recenlty in 2008, a small revision took place during the world congress in Shanghai.

However GIA enforced their own cut grading system in 2003 which resulted in significant controversy between experts worldwide. Although the introduction of an excellent grade for polish, symmetry and proportions the triple EX is now adapted by all grading laboratories.

Apart from the normal procedure for grading natural polished diamonds, there are still concerns regarding alteration techniques such as:; coating, crack filling, alteration of the color by cyclotron irradiation, and HPHT treatment. These techniques complicated the task of grading for the certificate laboratories in many aspects. The main challenge then became to detect and disclose these treatments which enforced the grading laboratories to implement a series of sophisticated research instruments including UV-VIS spectroscopy, FT-IR spectroscopy, Raman spectrometry and photo-luminescence spectroscopy. These techniques were introduced together with highly educated personnel and multiplied the cost for a reliable certification department.

From the electronics industry came another challenge: synthetic diamonds. The first reports were made by GIA in 1971 but to detect all synthetic variations took extended efforts and the goodwill and the cooperation of the electronic producers of these synthetics. Today all renowned institutes are able to detected synthetics by screening the total throughput of all certified diamonds for shortwave UV transparency and then consecutive specialized analysis.

Automation is another aspect of the grading process. HRD is using automatic color grading with their luminescence system since 2007. Automatic cut grading will become a reality in the near future. Hearts and arrows are graded by HRD without any human interaction which assures the objectivity to the ultimate level.

5 Conclusion

Like in most evolutionary processes, the triggers for breakthrough innovations consist of a cascade of events.

At first, independent technology providers like Sarin, Octonus and Ogi gradually replaced the experienced and "secret" skills of the diamond manufacturers with a scientific approach.

Secondly, grading laboratories were the first to adopt the newly implemented technology, in the first place for their own benefit. But as a consequence, this lead to more stringent tolerances in the quality grading of polished diamonds.

Thirdly, the impact of the improvements of the grading techniques forced the manufacturers to optimize their industrial diamond processing techniques and the quality control of their finished products, forcing them into considerable investments.

The scientific approach created much more transparency both on the technical field of the verification of the expert's skills and on the commercial aspect of trading caused by the easier crosschecking of quality and prices of the polished.

The Author

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Started at HRD, certificates department to set-up the certificates department for polished diamonds.
Projects:

- participant in the establishment of the International Diamond Grading rules, IDC-rules
- optimization of the dark field illumination of the HRD gemological microscope
- design of the polished diamond manipulator of the HRD microscope.
- design of an improved proportion measurement device
- coordinator of the research project for automatic colour measurement of polished diamond, supported by the Flemish government.
- author of the syllabus for the HRD course for grading polished diamonds used by the Gemological Institute of HRD.

1987-2005 - Managing Director, partner of Diamcad
The pioneers vision of Diamcad was the precision polishing of expensive diamonds. One of the most challenging tasks was the selection of a competitive engineering team.
Projects :

- design of an ultra stable polishing mill with accurate adjustable wheel position.
- development of a completely new technology for accurate measurement of the geometry of a rough diamond and precise location of the inclusions.
- issuing of an successful patent with the Russian Company Octonus for allocation of inclusion in rough diamonds.
- the design and development of a diamond laser cutting machine, giving the unique possibility for pie-sawing
- co-founder of the Diamscan daughter company; developed state of the art tomography technology for building an extremely accurate concave 3-D map of rough diamonds, an IWT co-financed research project with the Flemish government.
- the Diamscan team set milestones in the development of advanced optimization algorithms to optimize the polished yield of the mapped rough diamond.

2006 - Managing Director, partner of Matrix Diamond Technology
Matrix Diamond Technology took a choice without-compromises in the setup for the processing quality of the rough study and for the manufacturing plant.

2009 - Founder of Van der Steen Diamond Technology
Running projects;

- development of holo-tomography for automated inclusion measurement in diamond
- the application of data-parallel processing with GPU technology to accelerate the generic optimization algorithm