Planning Removal of Cutting Induced Sub-Surface Damage

It is well known that cutting gem material results in surface grooves caused by the successive grits, and the importance of their elimination in the final polish is a given. Equally important, but less well understood, is the associated sub-surface damage consisting of a network of micro-fractures. If the gem material has cleavages, then induced sub-surface damage in the form of insipid micro-cleavage beginnings (or "starts") contribute to the damage. The cleavage "starts" can be on any gem surface regardless of cleavage orientation, and to depths greater than the initiating sub-surface micro-fractures. Several very good articles have been written about the sub-surface damage, with actual measurements of the depths to which it extends. It turns out, however, many factors influence that depth. These variable factors complicate the task of preparing a practical plan to completely eliminate the damage in finished gems.

Elimination of all sub-surface damage from gems is important in several regards. First, the appearance of the gem and its brilliance can be seriously compromised if the sub-surface damage is sufficient to "scatter" or attenuate light. The resultant gems may seem less bright than expected, have less dispersion fire, or in general appear a little "sleepy". Often the sub-surface damage causing these problems is not even visible unless viewed at extreme magnification. Another consequence of sub-surface damage is unexplained chips or breakouts on any facet edge. The problem can be more apparent on culets, keels, corners or girdle edges, and can reach catastrophic proportions if the gem material has cleavage. Another problem may be polishing attempt failures on facets oriented in a plane near a cleavage, or occasionally for some material nearly perpendicular to a cleavage that is parallel to the lap rotation direction. The micro-fractures and insipid cleavage "starts" cause a series of marks resembling scratches, pits, and in extreme cases even mica-like layer separations that never seem to polish away. Finally, without eliminating all sub-surface damage, failure of the finished gem may occur at

some future time. Often this failure occurs when some unfortunate jeweler is either setting the gem, or is using steam or ultrasonic devices to cleaning jewelry the gem is set in. The micro-fractures and cleavages "starts" form stress "notches" that become failure focal points any time the gem is stressed. Pressure from the setting, high-energy vibrations, or thermal expansion caused by heating can, and has, resulted in broken stones.

As previously mention, precision determination of sub-surface damage depth can be complicated. There are many variables in damage depth, that include the nature of the gem material, the coarseness of the lap grit, the nature of the lap, and how aggressive the cutter was in making the cut. The greatest variable with material is not its hardness, but its toughness. The more fragile materials experience greater damage depth, and with cleavage considerably more. The larger the grit size the greater both the surface and sub-surface damage. The extent of damage cause by grit size can be different for different lap types. The harder metal bonded diamond laps cause greater damage than either epoxy bonded or well broken-in hand charged laps. The faster a lap is run, and the greater the cutting pressure applied, the greater the sub-surface damage. A heavy hand does accelerate cutting speed, but the price paid in greater material loss, lap damage, and the extra time required in more extensive damage elimination efforts, may be more important than the initial time saved was worth.

All these variables are more than most cutters care to contemplate. To simplify matters a bit, the following table of grit size and damage depth allowance ranges is suggested.

Lap Grit Size	Depth Allowance For Lap Induced Sub-Surface Damage		Girdle Width Reduction Allowance For Sub-Surface Damage Elimination	
	Minimum Depth (mm)	Maximum Depth (mm)	Minimum Diameter (mm)	Maximum Diameter (mm)
80	1.050	2.600	2.100	5.200
180	0.350	0.850	0.700	1.700
220	0.250	0.600	0.500	1.200
325	0.120	0.300	0.240	0.600
600	0.06	0.160	0.120	0.320
1200	0.030	0.070	0.060	0.140
3000	0.010	0.030	0.020	0.060
8000	0.005	0.010	0.010	0.020

The table depicts a maximum and a minimum depth to use in estimating and planning for damage removal. For the most part these values are close to the actual extremes likely to be encountered. The girdle width reduction values are just twice the associated facet depth values to reflect damage to depth to both sides of a gem, and are included as a convenience in planning gem size. It is important to note the table values are just broad guidelines, and not precision determinations. The mentioned variables can be dealt with as generalities using the maximum and minimum depth values shown. Starting with a mid-range value for the coarsest grit to be used, consider that tougher materials with more resistance to damage may suggest selecting a value closer the minimum. If the material were fragile, a value selection nearer the value maximum would be appropriate (See toughness listing below). Using a hard lap, or aggressive technique, suggests selecting a depth closer to the maximum. A soft lap and gentle touch suggests selecting a value nearer the minimum. Personal cutting experiences may influence the damage depth estimate. It is important to note that the coarsest grit damage depth estimate is a

maximum that includes all the lesser grit depths. In planning the total damage depth the lesser grit depths are not added. They are just used as a minimum depth removal for that grit stage, and collectively equal the coarsest grit damage depth.

The table is importance as a guide in preparing a cutting plan. To illustrate the point, consider this somewhat overly simplistic example:

> **Assume the gem to be cut is quartz, a relatively strong damage resistant material. Lower lap speeds and lighter pressure techniques will be used to lessen stress, which suggests even shallower damage depth. The cutting plan includes the use of a #80 lap, a #600 lap, and a #3000 pre-polish lap, all of which are well used and less likely to cause deep damage. All things considered it is reasonable to assume that in this example the cutting damage depth will be near the minimums shown in the table.**

1. **First cut is with the #80 lap, and results in damage to a 1.050 mm depth. Note that this is the maximum depth to be removed including all lap grit sizes through final polish. The successive damage depths tend to overlap rather than add.**

2. **Second cut is with a #600 lap, and the mast or depth adjustment of the faceting machine is set for a cutting depth of 0.900 mm (1.050$_{\#80}$ minus 0.060$_{\#600}$). This leaves a depth of 0.060 mm still to be removed.**

3. The third cut is with a #3000 pre-polish lap, and the depth adjustment is set for a 0.050 mm cut ($0.060_{\#600}$ minus $0.010_{\#3000}$). This leaves a modest balance of 0.010 mm, the #3000 grit lap damage depth, to be removed during final polish.

Note the total removal depth is 1.040 mm ($1.050_{\#80}$ minus $0.010_{\#3000}$) prior to the final polish. The final polish as a minimum must remove 0.010 mm. To manage gem size, the width of remaining gem material at the end of the first grit must be 2.100 mm greater than the planned finished gem width. This allowance is the same as twice the initial grit damage depth as show in the table. If experience indicates the final polish process tends to require a bit more material removal, then an additional amount can be assigned to the final pre-polish lap damage depth.

To illustrate the impact of skipping the pre-polish lap step, note that 0.060 mm must be removed during the final polish if done directly from the #600 grit lap. This is six times more depth removal in final polish than would be required if a pre-polish was used. The extra time, and possible facet precision loss, makes the practice questionable for a quality gem.

If the example seems to be very wasteful of rough material, it is. The solution is to reduce the amount of material that must be removed to eliminate the sub-surface damage. Note

that if a #180 grit lap is used to finalize the pre-form rather than finishing it with the #80 lap, then the gem diameter loss allowance drops from 2.100 mm to just 0.700 mm. Even more material saving is possible if the final pre-form grit is just #600, with a total diameter reduction allowance of just 0.120 mm. The bottom line is that material must be removed to the induced damage depth. Planning greater amounts of material to be removed with faster coarser grit laps, or opting for longer fine grit lap cutting times, with great lap wear and tear, are the choices. It's the cutters job to consider what is involved, and make the choice. A good trim saw rather than grinding to remove material and help shape a gem pre-form can be beneficial, but even a narrow trim saw blade has a relatively coarse grit size equivalent (#180 more or less) that must be accounted for.

Every cutter will develop unique impressions of different gem material sub-surface damage sensitivities for use in planning cutting depth detail. To provide an initial general impression of gem material sensitivity the following materials are listed in order of commonly encountered sensitivities:

1. **Spodumene, (Kunzite a challenge)**
2. **Fluorite (miserable)**
3. **Apatite (yellow a challenge)**
4. **Fire Opal (some sources more than others)**
5. **Sunstone, Oregon (twinning/schiller more sensitive)**
6. **Topaz, treated (reputation worst than experience)**
7. **Garnet**
8. **Zircon, treated**
9. **Tourmaline (Black Schorl, an be a challenge)**
10. **Quartz, any**
11. **Corundum, any**

The first four in the range should be considered especially sensitive to damage, the last three most strongly resistant, and all those in the middle moderately resistant. These correspond to maximum depth allowance, minimum depth

allowance, and mid-range depth allowance respectfully. Gem material toughness can also be subjectively determined by referral to Glenn and Martha Vargas's "Faceting for Amateurs". Other information sources exist, and as stated personal cutting experience can suggest a relative toughness to be used instead.

Good damage removal planning will result in better-cut gems, less cutter frustration, and ultimately greater retention of gem rough. Problems related to insufficient damage removal will nearly always represent a greater loss in time, material, and ultimately lower net recovered value than that expected from a planned removal of induced damage. Awareness of the requirement is the first important step in that direction. Grit damage planning can, with experience, become painlessly intuitive.

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