

Polishing: the basic principles

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Introduction

Polishing, whether done mechanically by hand on a polishing wheel or by machine or by electrochemical or chemical means, is not a 'black art' but a technology based on sound scientific principles. Understand those principles and you should improve your polishing efficiency, consistency and quality at reduced costs. In this paper, we look at the basic principles of the technology of mechanical polishing which is the most frequently used process and some of their implications for industrial practice. It applies to all materials and alloys just as much as to gold jewellery.

This paper is based on sections of the new World Gold Council publication, *Handbook on Finishing* by Dr Valerio Faccenda (1), details of which were published in the last issue of *Gold Technology*, No 25, April 1999.

Reflectivity and surface roughness

A perfectly flat, defect-free smooth surface will reflect incident light uniformly and efficiently and it will be highly reflective; we say that it has a high lustre or is brightly polished. If we examine the flat surface of an unpolished piece of jewellery under an eyepiece (loup) or, preferably, under a microscope, we would see that it was scratched, with scratch lines criss-crossing at all angles. A surface ground with emery paper would be heavily scratched. It may even feel rough to the touch by hand. These surface imperfections cause incident light to be reflected in different directions and hence the surface appears to be less reflective, i.e. less lustrous or bright, and is less well polished.

In cross-section, at high magnification, the surface would

appear like a mountain landscape, as illustrated in Figure 1(a). The depth (and density) of the scratches can be measured and is expressed quantitatively in terms of **surface roughness**. This can be measured by several types of readily available instruments, some based on sliding a diamond-tipped stylus across the surface to be measured ('profileometer'). As a surface is polished, it becomes smoother and more reflective. The number and depth of the scratches decrease and the value of surface roughness decreases. Thus, the process of polishing can be measured in quantitative terms.

Mechanisms and principles of polishing

There are 2 basic mechanisms by which a surface becomes smoother and polished.

- Removal of surface material, e.g. by abrasion (grinding, filing, buffing) or by electrolytic or chemical polishing

- Flattening and smoothing of the surface by mechanical working (burnishing)

In the **abrasive removal** of material, the surface is contacted by hard abrasive media particles that move across the surface and plough off material, leaving a series of scratches whose depth is determined by the abrasive particle size. The use of successively finer abrasives, one after the other, enables a smoother surface, i.e. a lower surface roughness, to be attained.

In **burnishing**, the surface is smoothed by plastic deformation of the surface layer through a mechanical working treatment that may involve hammering or frictional contact by a harder material such as

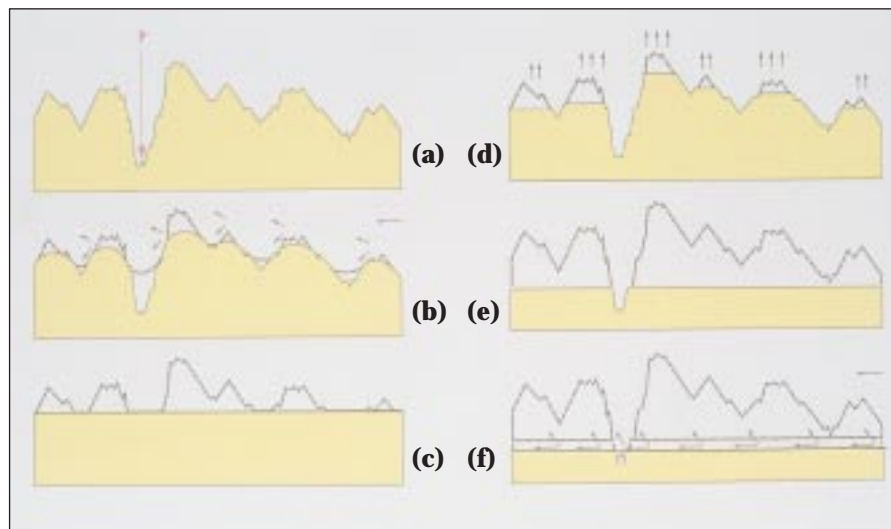


Figure 1 – Evolution of surface roughness in electrochemical and mechanical finishing:

(a) - starting surface;

(b) - mechanism of mechanical finishing

(c) - result of mechanical finishing;

(d) - mechanism of electrochemical polishing;

(e) - result of electrochemical polishing;

(f) - surface after electrochemical polishing and subsequent mechanical polishing

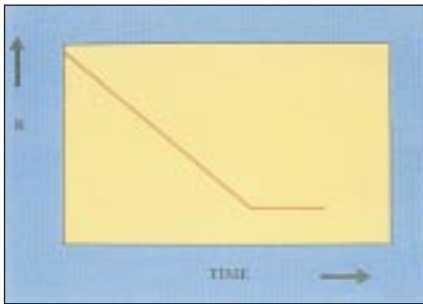


Figure 2 – Influence of treatment time on the evolution of surface roughness for a given medium (schematic)

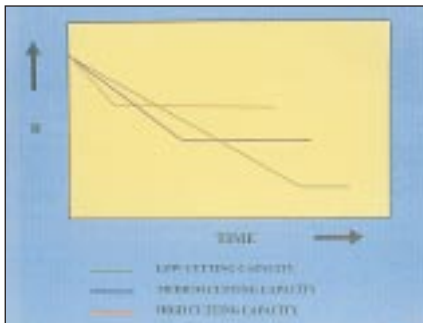


Figure 3 – Evolution of surface roughness as a function of time for 3 different finishing media (schematic)

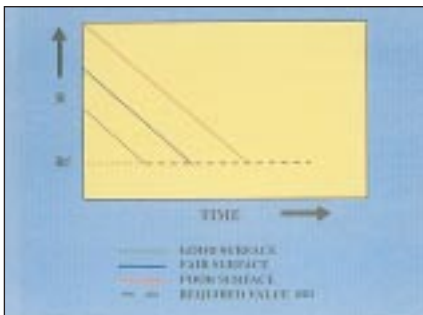


Figure 4 – Influence of the starting condition of the surface on the time required for finishing (schematic)

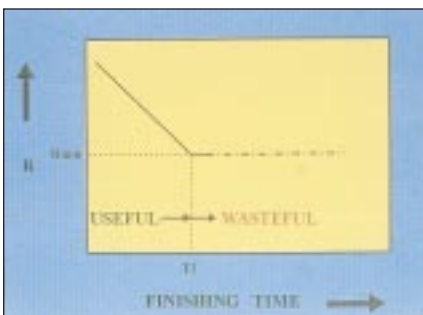


Figure 5 – “Useful treatment time” and “Wasted treatment time” during polishing

steel or porcelain balls. This is often the final step in the polishing process, following abrasive removal steps.

The evolution of surface roughness in mechanical and electrochemical polishing is shown schematically in Figure 1 (a-f). During polishing, the surface roughness decreases with time. However, there are a number of points that are fundamental to the mechanical polishing process, using abrasive media, whether done by hand on a buffing wheel or by machine:

(1) For a given abrasive type and particle (grain) size, there is a **minimum surface roughness** value that can be attained, irrespective of the length of time the jewellery continues to be processed, as shown schematically in Figure 2. Once this value has been reached, further processing only brings about a progressive loss of fine surface detail as well as continued metal removal.

(2) The **rate of metal removal** depends on the abrasive medium used. The more abrasive media with a coarser particle (grain) size will cut deeper and remove more metal than a finer, less abrasive medium. Thus, the coarser medium will remove metal faster but the finer abrasive medium will allow a lower minimum surface roughness to be achieved. This is illustrated schematically in Figure 3.

(3) The **time taken** to achieve the minimum surface roughness value, for a given medium, will depend on the initial surface roughness of the jewellery, as shown in Figure 4. A rough surface (for example, as found on a casting) will take longer to process than a smoother surface (for example, as found on a stamping). Thus, it should be apparent that the better the surface condition obtained in the earlier manufacturing stages, the less time and effort is needed to obtain the desired level of polish.

It should be obvious, too, that polishing will only occur in those regions of the jewellery piece accessed by the polishing medium. Large media will not access small or deep recesses, for example. Hence size and shape of the media are also important. Some of the practical implications of these basic points are discussed in the next section. The

mechanism of electropolishing is not discussed here but can be found in the *Handbook on Finishing*, published by World Gold Council.

Practical implications

In the previous section, we noted a fundamental rule that for a given finishing medium and particular grain size, there is a minimum value of surface roughness that can be attained. When this value is reached, Figure 5, a continuation of the process leads only to progressive loss of material and fine surface detail and is thus wasted time. In machine polishing, this means that jewellery items of varying size, shape and surface condition should not be mixed together in the same batch, as each type probably requires different treatment times. There is the risk that, after a given treatment time, some objects have not reached the minimum surface roughness, while others are already in the wasteful phase of loss of detail and material.

As seen in Figure 3, coarser media cut faster but finer media allow lower surface roughness values to be attained. Use of a fine medium alone to achieve the required polish, i.e. a low value of surface roughness, takes a significant time. However, the total time required for a good finish (low surface roughness) to be attained can be significantly reduced through a multi-step process whereby a series of media are used in succession, each one being finer than the one before. This takes advantage of the faster cutting of the coarser media, with the change to the finer media being made when the minimum roughness value of that medium has been attained. In Figure 6, three abrasive media are used in succession, with their respective minimum roughness values being reached at points A, B and C.

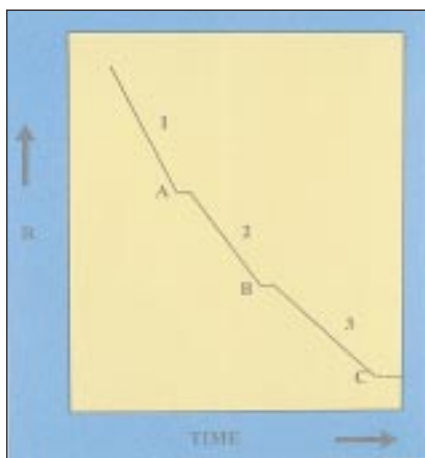


Figure 6 – Schematic representation of a multistep finishing process, where finer media are used in succession (points A and B denote the change to a finer medium)

In some equipment, the results obtained by use of certain finishing media can be improved through the addition of suitable chemical solutions: these can be degreasing, detergent, acid or specialized for particular uses.

Independent of the equipment and of the finishing medium, the time to achieve the minimum roughness is also influenced by the initial condition of the surface, as noted earlier, Figure 4. The operator is a further important variable, frequently overlooked: the apparatus, the finishing medium, the object to be finished do not take decisions, the operator does!

During the testing and optimisation phase of the finishing process for a particular type of jewellery, it is always necessary to carry out a careful set of tests to find the optimum process conditions for the actual objects to be finished: different finishing media, quantity ratios (jewellery:media), times and added solutions should be tested. When the most favourable operating conditions have been found, they should be accurately maintained for each batch processed. If something goes wrong, a critical scrutiny of the process variables is necessary, including the operator. He may have made an error.

Influence of Equipment type

The equipment used in mechanised finishing also plays a significant role in the time taken to achieve the minimum surface roughness for a given media. This is a reflection of the useful energy – force and motion – imparted to the jewellery and media. In general, for a given abrasive media, the rotary barrel (tumbler) will take longer than a vibratory barrel, with the centrifugal disc and centrifugal planetary barrel taking the shortest times (see graph, for example, in references 1 and 2). However, the selection of machine is not made solely on processing time but on other factors such as the incidence of surface damage ('nicks') caused by impingement, cost, etc.

Media

The task of the finishing medium is to control and reduce surface roughness through either abrasive action or by

plastic deformation of the surface, thus polishing the jewellery items and giving them the required sheen. In mechanised finishing, media should have a number of attributes:

- They should be able to access all regions of the jewellery surface to be polished. Thus, size and shape are important.
- They should present fresh cutting surfaces to the jewellery, so some wear is necessary.
- They should be wear resistant, to avoid frequent replacement.
- They should not cause any sedimentation in the machine, whereby jewellery and media separate into layers, reducing polishing efficiency.
- At the end of the finishing step, the media should be easily separable from the jewellery. The media should not lodge or jam in the jewellery.

Abrasive media control the surface roughness of the jewellery through the abrasive particle (grain) size and the relative amount of active material. The process is influenced by the ratio between size of the finishing medium and the size of the pieces to be finished as well as their shapes and their relative specific gravities. The wider the contact between the finishing medium and the surfaces and edges of the pieces to be finished, the better the results.

A range of finishing media, with different cutting capability and with different gauge sizes, are commercially available. The abrasive media can be designed for fast, medium or slow cutting rate. As discussed earlier, the smaller particle size media provide a better finishing (lower surface roughness) than larger particle size media; however, the latter cut faster.

The ratio between the amount of finishing media and the amount of jewellery pieces to be finished deserves special attention. Whilst each supplier gives his own particular advice, experience shows that the preferred ratio by volume between finishing media and pieces to be:

- Ceramic abrasives 4:1
- Plastics (containing abrasives) 7:1
- Non-abrasive ceramics (e.g. small porcelain spheres) 10:1
- Small steel spheres 8:1

These ratios serve as a good 'rule of thumb'. In all cases, the ratios between finishing medium and pieces to be finished should be optimised for each particular production and, as a rule of thumb, the volume of the pieces to be finished should always be no more than 25-30% of the total volume. Otherwise the probability of impingement between the jewellery pieces being finished increases, increasing the risk of damage such as the formation of 'nicks'.

Conclusions


The basic principles of mechanical polishing have been outlined and demonstrate that finishing of jewellery is a technology, not a 'black art'. The principles apply equally to polishing by hand on a wheel, as practiced in many workshops worldwide or to polishing by machine in an advanced factory. Understanding these principles and their implications should enable a jewellery producer to attain an improved, more consistent quality of finishing with less gold loss and at lower production costs.

References

- 1 "Handbook on Finishing", V.Faccenda, published by World Gold Council, London, 1999.*
- 2 See graph by D.Goodrich, reported by M.Grimwade, *Gold Technology*, no.15, April 1995, page 20

* see page 34 for details of purchasing this Handbook.



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