ABSTRACT

Because of the great efficiency of transfer of energy in the impact process, some purveyors and some users are not fully aware of the parameters of process engineering. Process engineering is important in two and, possibly, all three, of the basic divisions of the impact process, namely, shot peening, fine abrasive blasting and coarse abrasive blasting.

It is incumbent upon participants, manufacturers of machines and media, to promote effective and complete process engineering to ensure customers' optimized costs and productivity. It is also important that the industry be postured on engineering data to which process parameters can be rationalized and which can serve as guides in anticipating costs and design requirements.

This paper will illustrate the leverage of the elements of the process on productivity, showing the important effect of process speed on costs and dealing with issues of erosion, energy, media consumption and machine efficiency. A description of how losses or "cost leaks" occur is included. Methods of developing process parameters and using them to verify engineering findings will be demonstrated.

The aggregate theme is that sensitizing customers to the importance of good specifications for media, equipment and operations renders the industry more effective and gains optimum respect among present or prospective users. Also included is the proposition that the industry must demonstrate continued advances in its knowledge of itself and of its capabilities in order to continue to meet increasing reliability standards in the aircraft industry and in the high production industries. Reflections will be made on the role of the process in those industries and the prospects for the future. In particular, note will be taken of the newly available plastic abrasives which represent a key advance.

In conclusion, the generality is addressed that the more confidence prospective users have in the ability of an industry to anticipate results and control processes, the more likely they are to use it.
INTRODUCTION

It is fitting to give a keynote address concerning the engineering of impact processes in the nation where these processes were invented. One can imagine the scene at a naval base in, I believe, 1872, when impact blasting was first tried. As workers and engineers looked on, the steam engine cranked up the power of one of Dr. Tighlman's compressors, which was then fitted into a rudimentary pressure pot of bolts and gaskets. This, in turn, blasted sand out through a hose on the surface of a test piece or, perhaps, on the iron hull of a small ship encrusted with barnacles and rust. Imagine the reaction of those who first saw this magnificent dispersion of energy on a surface, which could grind away the most stubborn contaminants, performing the day's work of 100 men in minutes and doing it significantly better. It is likely that there were some civilian engineers and officers of the Royal Navy present who breathed a great sigh of relief.

The inventiveness of the naval architects of the Confederacy in the American Civil War was credited for the construction of the first real iron clad that would see battle even though the British Admiralty had been experimenting with armor ing. In response, the Union had, of course, commissioned the development of the Monitor, which opposed the Merrimack in the historic battle at Hampton Roads. After this, it was clearly evident that the Royal Navy would have to convert metal ships to continue to fulfill its historic role of maintaining the Pax Britannica which, in addition to protecting the Home Islands and the Empire, included keeping European powers from meddling in the affairs of the United States. The conversion to metal presented enormous corrosion and cleaning problems, for which Tighlman provided the means to solve. Perhaps the cleaning problems delayed the process of using metal, which waited for a desperate need before it appeared.

Throughout the years, we have all been fascinated by this impact process as we have become more involved in it. The transfer of energy from electricity to work upon a surface is extraordinarily efficient. And, like all processes which have been addressed by competent men and women, both theoretically and practically, productivity has improved substantially during its first 114 years of use.

We are perhaps about the fifth generation of stewards. Our concentration has been in replacing chemical cleaning with mechanical, and in developing the great science of shot peening, which is so terribly important in aircraft metallurgy, and of potentially even more importance in the automotive industry and in the conservation of energy and materials. It was our predecessors of the second generation who introduced metallic abrasives. The third generation contributed what we might call fine abrasives. The fourth brought forward organics and the first use of glass beads. Now we have hard and soft plastics, so as not to feel too complacent.

Developing the Technology

Our industry will be one of growth and expansion provided we, as the stewards of the technology, continue to maintain and advance our understanding of the process and its dynamics, and communicate that understanding to our customers and to those who use the process and
depend on us for guidance. It is also incumbent upon us to pass our experience on to the forthcoming generation. To achieve those goals, we may have to recall some of the basic principles, as we may forget them ourselves, enamored as we are of the nuances of advancement and the substantial and complex applications that we are developing.

An essential is to maintain the quality and reliability of our work. A particular point on which, perhaps, we have been lax, is in recognizing the importance of sensitizing customers, and others involved, to the need for good specifications in media, equipment and operations. Quality media will not work without good equipment, nor will quality equipment work best without quality media. Neither will work without good process instructions. The critical issue in shot peening and abrasive blasting is process engineering, which creates optimum results in economy and productivity. Quality depends upon conscientious control of the process. This quality has a significant value. Good process engineering can also defend competent purveyors against the inadequate and incompetent, if they appear.

Controlling the Processes

It takes some time to explain the dimensions and dynamics of the process or the essential elements of optimizing costs and productivity. In particular, in the cleaning process, the elements of speed, erosion, energy and consumption and their relevance to efficiency is sometimes obscured by the drama of action in blast cabinets or rooms.

In most cases, the issue of cost is largely determined by the time it takes to process individual work pieces and by the speed of media action on the surfaces treated. Media impact consumption, cyclone or reclaimer loss, energy and part protection are the other considerations to be melded together. Further, surface finish specifications must be met; however, the most important of all may be achieving peening saturation and coverage.

It is important that our industry's posture and character be based on good engineering and data to which process parameters can be rationalized. Data is necessary to good engineering. There must be guide posts in anticipating costs and design requirements. Emphasizing process engineering demonstrates the industry's ability to control processes and anticipate results. It is key to inspiring confidence in the industry among prospective users.

To the untrained eye, the results of any form of blast cleaning are dramatic. Competent industrial engineers, however, will immediately want to know how to maximize the process, recognizing that flow rates and particle velocities are ultra critical. We all know the difference between a 1/2-1/4 and a 3/8-3/16 suction head. When I say this, I'm sure that you are immediately formulating comparisons in your minds of CFM and energy requirements and nominal flow rates at optimum pressures. You will then think of the consumption of the abrasive and particle count and finish. Finish notwithstanding, you will use the smallest particle that will exert sufficient energy upon the surface to perform the cleaning function...
required, because that particle will produce the greatest number of impacts per pound. Particle count is a third power function; it changes rather rapidly. With regard to machine design, feed rates and reclaiming to produce speed is the justification for well-designed machines. Machines must be designed around feed rates and dust collector drives which, in turn, drive reclaimers.

**Media Engineering**

Probably the first principle of Process Engineering that we need to practice, and encourage our customers to practice, is that at least three different sizes of media should be tested for cleaning speed as the first step in any application. Labor costs and labor productivity are the critical variables, and are materially affected by the size of abrasive used. The curves in Figures 1A and B depict laboratory speed-of-cleaning tests performed under controlled conditions using glass beads of different diameter ranges. Three specimens of different materials were tested, each treated to provide a uniform layer of oxide to be removed.

![Graph](image)

**Figs. 1A and B** Speed of Cleaning Tests Show Effect of Bead Size

The curves show the increased speed using smaller beads; but, the important point is the difference between the optimum size and the next size. If a wrong size is selected, speed can be materially affected. The process slows; labor costs increase.

In the case of glass beads, particle shape influences consumption costs and process performance. The higher the roundness of material, the less the impact consumption. Excessively angular particles in the size range used will cause metal erosion and a change of tolerances. In the case of aluminum oxide, shape is critical to consumption and performance.

Nozzles and their application to a work piece and the number of work pieces come together to justify automated equipment. The critical variable in the amount of work that could be done and in labor productivity is the feed rate of the correct size of abrasive particle. If one man can operate a machine with twenty nozzles feeding
two pounds per minute each, or two machines with ten nozzles, or four machines with five nozzles, the essential cost of labor in the process is lowered, assuming that we can design equipment in which twenty nozzles will do close to twenty times the work of one. With the offsetting of depreciation for labor costs, the recovery of capital is likely to be very favorable.

Fig. 2: Labor Costs Decrease as Number of Nozzles Increase

Cost Leaks

When tests optimize speed, and multiple nozzle automation optimizes feed rate, labor cost becomes proportionately less per unit of output. Since the same amount of abrasive has to be thrown in order to accomplish the work, impact consumption and cyclone loss become the next most important direct-cost considerations. In certain applications with glass beads using the high feed rates of an automated machine, a reduction in speed might be accepted in order to reduce impact consumption. Impact consumption, at a given Almen Intensity, is less for a larger bead as opposed to a smaller. Generalized dimensions of this variance in consumption have been published and are available for rationalizing tests. Generally, because of the variance in part geometry, a consumption test has to be conducted for each size of abrasive being considered.

Table 1, on the following page, identifies different sizes of glass beads, and includes the minimum percent roundness that should normally be required for the lowest possible consumption at commercial prices.
### Table 1 Particle Count and Minimum Particle Roundness Required

<table>
<thead>
<tr>
<th>US Sieve</th>
<th>Sieve Opening In Microns</th>
<th>Particle Count/Pound</th>
<th>Minimum % True Spheres</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-30</td>
<td>850-600</td>
<td>990,000</td>
<td>65</td>
</tr>
<tr>
<td>25-45</td>
<td>710-355</td>
<td>3,740,000</td>
<td>65</td>
</tr>
<tr>
<td>30-40</td>
<td>600-425</td>
<td>2,800,000</td>
<td>65</td>
</tr>
<tr>
<td>40-50</td>
<td>425-300</td>
<td>7,900,000</td>
<td>65</td>
</tr>
<tr>
<td>40-70</td>
<td>425-212</td>
<td>13,600,000</td>
<td>75</td>
</tr>
<tr>
<td>50-70</td>
<td>300-212</td>
<td>22,400,000</td>
<td>75</td>
</tr>
<tr>
<td>50-80</td>
<td>300-180</td>
<td>37,700,000</td>
<td>70</td>
</tr>
<tr>
<td>60-100</td>
<td>250-150</td>
<td>63,000,000</td>
<td>80</td>
</tr>
<tr>
<td>70-140</td>
<td>212-106</td>
<td>143,000,000</td>
<td>80</td>
</tr>
<tr>
<td>100-170</td>
<td>150-90</td>
<td>302,000,000</td>
<td>85</td>
</tr>
<tr>
<td>120-200</td>
<td>125-75</td>
<td>514,000,000</td>
<td>80</td>
</tr>
<tr>
<td>140-230</td>
<td>106-63</td>
<td>864,000,000</td>
<td>85</td>
</tr>
<tr>
<td>160-270</td>
<td>106-53</td>
<td>1,134,000,000</td>
<td>85</td>
</tr>
<tr>
<td>170-325</td>
<td>90-45</td>
<td>1,877,000,000</td>
<td>85</td>
</tr>
</tbody>
</table>

Figures 3A and B further demonstrate the increase in media consumption if excessive angular and other non-round particles are included. Angular particles are less resistant to fracture than spherical particles. The use of poor quality glass beads results in substantially higher process costs, just from excess consumption.

![Figures 3A and B](image_url)

Figs. 3A and B Increased Media Consumption

The other form of consumption, cyclone loss, often occurs in shot peening, or cleaning applications using coarser beads. If the percentage of fine beads is too high, cyclones that are set properly to remove broken particles will also remove the excessively fine beads, depriving the user of a significant percentage of the value of his...
It might be said that good process engineering prevents many "cost leaks" that can occur as a result of inadequate or improperly enforced specifications. Well-designed equipment operates best when the specifications are correct and enforced; that's how the whole process operates best. And if, as an industry, it is not our intention to provide the best we can to our customers, then we can expect to lose both respect and profits. Profits which are paid to us by our customers when we provide them the best possible service to meet their needs. If we don't meet their needs well, cause them difficulties or fail to respond, then why should they pay us any special reward?

Educating Customers

For those designing and producing well-built and well-engineered equipment, sensitizing customers to the real technology of the process promotes understanding of the need to buy the state-of-the-art to maximize productivity and optimize performance. What better method than undertaking good process engineering is there to demonstrate that the incremental cost of well-engineered equipment is quickly returned to the buyer? In particular, in showing the importance of the media, does one not prove the need for the best possible reclaiming to maintain constant process conditions and to reduce the potential of surface erosion?

The published parameters of speed, consumption and surface finish are the guide posts that can be used, in the case of glass beads and steel shot, to show engineers that their test findings in specific applications are falling into a prospective range.

This industry has evolved tremendously in relatively few years. Today, we are in the business of cleaning and peening the most sophisticated parts in the most sophisticated manufacturing operations of the world's most sophisticated industries. This aerospace technology industry offers benefits to other industries with less demanding, but still important applications.

There is, for us, a transcendence from concern about reliability in the aircraft industry, to concern for costs and productivity in the automotive industry, in parts manufacture, appliances, instruments and so forth. In making that transition, it is necessary to understand and appeal to the needs of prospects and customers, and to meet those needs with excellent process development. Practicing good process engineering even gives an understanding and a definition to needs, that of which customers or prospects might not even be aware.

CONCLUSION

In looking to the future of the fine abrasive industry, advancements in the technology of shot peening will likely be seen. In the next decade, the model peening equations now being developed will be commonplace in engineering curricula, bringing about a full understanding of the effect of the process.
On-going contributions in the replacement of chemical cleaning with mechanical cleaning will continue to offer dramatic benefits. Many of the toxic waste sites that seem to push out of the earth almost weekly have been dumps of cleaning type materials. Utilizing the advantage of fine abrasive blasting, particularly with glass beads, to replace chemicals is cheaper, safer and totally avoids the pollution problem in most applications. The new, hard, blocky plastic abrasives have added an important dimension. In using them, coatings can be removed from metals without changing the surface at all.

New applications for developing our industry are unfolding as new ideas are put to work in atomic energy, power transmission, improved metallurgy and elsewhere. There is a great deal more shot peening to be done in the automotive industry; a great deal more cleaning to be done in the chemical process industry; and new developments in the traditional non-aircraft applications are likely.

The contribution of an industry, like the contribution of a corporation, stems from innovation. Through innovation and application of methods and concepts already developed, this industry can demonstrate continued advances in its knowledge of itself and of its capabilities. These advances are necessary to meet increasing standards in the aircraft and high-production industries, and to heighten confidence in the industry, particularly among prospective users.

However, we must also maintain the technology we have by using it and promoting it. We must protect those concepts which can easily be lost; those valuable nuances that can be obliterated by overzealous purchasing agents or other bureaucrats. And we must maintain the confidence and interest of the engineers and good managers whom we serve.

There are always going to be buyers who buy the cheapest and pay the highest price thereby.

Our customers are better served otherwise --- with good values.