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# Is progress in energy-efficient comminution doomed?

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ABSTRACT

Comminution is known to be an inefficient user of energy. This makes it the largest energy consumer in many mine sites and therefore a large component of cost. One would therefore have thought that improving comminution energy efficiency would be receiving the undivided attention of the mining industry, but this is not the case. This paper considers why this is so and what the future might hold, by posing and attempting to answer three questions:

- Is this really an important issue for the mining industry?
- If so, can comminution energy be substantially reduced in a reasonable time frame?
- What are the drivers that will motivate change, and what should now be done?

The conclusions of the paper are pessimistic in the sense that forces may be gathering that will demand that the issue be addressed across the industry in the relatively near future, but optimistic in the sense that there is a clear development path. There is much that can be done with what is already known, and considerable promise exists in new developments which can be realised through sustained and focused R&D, building on new knowledge acquired in the last 20 years. These are outlined in the paper. It is concluded that there is a case for a global initiative to significantly reduce comminution consumption over say the next 10 years through a partnership between all parts of industry and the research community, covering short, medium and long-term innovation.



## 1. Introduction and background

It is well known that comminution, particularly grinding, is the largest consumer of energy on most base and precious metal mine sites and a significant consumer in other commodities. Some defensible calculations suggest that it uses nearly 2% of all electrical energy generated on the planet (see Appendix A), and much more in mining-intensive countries such as Australia and South Africa. Mining companies are seeking to take costs out of their operations, and some are looking over their shoulder at the regulators who are threatening to impose costs on energy generated from fossil fuels to limit the world's carbon emissions in response to a perceived human-induced change in the climate (or have already done so). Why then is comminution energy consumption not more visible in the industry (and perhaps even government) as an issue worth addressing? This paper seeks to answer three questions which illuminate this dilemma:

1. Is comminution energy consumption actually important to the mining industry?
2. If so, can we reduce it substantially in a reasonable time frame, and by how much?
3. What are the drivers that will promote significant reductions in comminution energy intensity, and what should now be done?

In the course of addressing these questions we will consider new knowledge which has accumulated in the last 20 years, some of it without fanfare, and ask how it can be turned to good use.

In the preparation of this paper the author has consulted a number of experienced workers in the field from mining companies, equipment vendors, engineering companies and academia, and this paper reflects in part his interpretation of those views. A list of those consulted appears in the Acknowledgements and the author is grateful for their willing participation. However any foolish statements or mis-interpretations remain the author's responsibility.

## 2. Discussion

### *2.1. Is comminution energy consumption important, and is it perceived to be so?*

These are two different questions. Estimating comminution energy consumption as a proportion of total mine site

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consumption is surprisingly difficult to do accurately, although many have tried. Lack of published data and inconsistency in how total energy consumption on mine sites is calculated or expressed are the main culprits. However there is enough information around to arrive at figures that are good enough to answer the first question with sufficient accuracy for our purpose. Ballantyne et al. (2012) quote a figure of 36% of total mine site utilised power (in all forms), and 52% of electrical power, as being attributable to comminution in Australian copper and gold operations. In more general reviews Marsden (2008) reports 34% and a DOE report (2007) suggests 44%.

It is also important to remember that a significant amount of additional energy is expended indirectly in supporting comminution operations, particularly in the consumption of liners and grinding media. Musa and Morrison (2009) suggest that this could be as much as 30–50% of direct energy consumption. Although this impost is not borne directly by mining companies in terms of energy *per se*, it certainly is in terms of operating cost. Also if we are to do anything about our equivalent carbon emission intensity then it must be included in the mix.

The question of the proportion of world energy consumed in comminution is similar to the ancient conundrum about the number of angels which can dance on the head of a pin – interesting but not very useful. However the miracles of the internet allow one to do a rough calculation, shown in Appendix A. The result is 1.8%[1] which compares well with the 2% estimated by the famous and oft-quoted DOE report of 1981.

A similar problem attends the estimate of the 'true' energy efficiency of comminution. A commonly quoted figure for the efficiency in terms of the free energy of new surface produced is 1–3% (Fuerstenau and Abouzeid, 2002, based mostly on quartz studies). However Schoenert (1972) showed that the most efficient way of fracturing a rock in mechanical comminution is to load it between two platens until it breaks in tension. In these terms a crusher might then be 75% energy efficient (Morrell et al., 1992) and a ball mill 15% efficient (Fuerstenau and Abouzeid, 2002) in producing the same size distribution as single particle breakage. The balance of the energy is consumed in elastic strain which cannot be recovered, the motion of any charge, and the usual transmission and other losses. Much of this appears eventually as heat, as anyone who has stood at the discharge end of a large SAG mill will attest. The inability to recover elastic strain losses, and thermodynamic considerations, impose a practical upper limit on the potential efficiency of conventional comminution machines.

It is clear therefore that comminution energy costs are high and the process is inefficient, and these problems are reflected in operating cost, capital cost and possibly future regulatory constraints related to carbon emission mitigation. One would therefore expect the issue to be receiving the undivided attention of the industry, yet the evidence is that this is not so, far from it in fact. The reasons are many. The CEEC Roadmap (CEEC, 2012), developed at a 2-day international workshop of invited senior technical professionals from all parts of the industry in August 2012, identified the following impediments to a pursuit of improved comminution energy efficiency (this is not a complete list):

- Project valuation practices (e.g. NPV) do not capture the issue.
- Lack of support from senior management for alternative strategies.
- Inconsistent work structures and metrics across an organisation: the 'silo problem', leading to difficulty in seeing the whole picture.
- Current organisational practices, including KPIs, do not encourage maximising efficiency, particularly across silos.
- A focus on maximising throughput at almost any cost.
- The conservative, risk-averse nature of the industry; a reluctance to adopt new technologies (with some honourable exceptions).
- Lack of an open exchange of information, sometimes related to the protection of IP.
- A gap between project owners and engineers on one side and technology developers on the other, so technology transfer is more difficult than it should be. There is little incentive to be an early adopter.

These should not be seen as criticisms of the industry. They are a natural consequence of the risky capital-intensive nature of the business, and the human condition, and some companies are indeed addressing the issue through energy audits and benchmarking. However it is interesting to note that most of the problems are cultural, not technical, and thus perhaps harder to solve. The 'lack of senior management support' (which is not universal) is particularly telling; senior management will generally support whatever makes more money for the company, and if comminution energy is not on their radar then there is a reason for that. Either the issue is truly unimportant relative to the many others clamouring for management attention, or the problem is not being articulated or captured in a way that merits action. In this author's view the latter is more likely to be the case than the former.

This view was reinforced by the informal canvass of opinion conducted for this paper, mentioned earlier. In the end dollars drive everything, and if comminution energy is not seen as a serious impediment to profit it will not be addressed, except incidentally. A particular problem seems to be the understandable knee-jerk reaction that it is simply too difficult to solve unilaterally; other lower-hanging fruit gets the attention. Also vertically integrated companies which include very energy-intensive processes such as smelting give more scrutiny to those processes than to comminution. Overall the impact which comminution energy has on project value is not well understood because the metrics are often too primitive. For example downstream metal recovery is absolutely dependent on the judicious expenditure of comminution energy which in turn depends on mining method (particularly blasting), but these three are not usually treated as an optimisable continuum in financial analyses. Also the additional embedded energy mentioned below (liners and grinding media) and the associated pumps and conveyors are rarely considered in the mix and the magnitude of the problem is therefore underestimated.

The appreciation of comminution energy consumption as part of the project evaluation mix is growing, but it will usually only get attention where the project economics are marginal and savings are being sought, or where power is in short supply. The mining companies are in the driving seat for change as the clients of the engineering companies and equipment suppliers. In the end the service providers will do what the client wants.

However things may be changing. Potential drivers for change are considered further below.

### 2.2. How can we reduce comminution energy consumption, and by how much?

The science of comminution, and its associated phenomenon of mineral liberation (the main purpose of comminution in mineral processing), has advanced considerably in recent years. Some of the things we know now as R&D outcomes that we did not know 20 years ago include[2]:

[1] Nearly half of which is cement grinding.

[2] One might argue that some of these were known intuitively to competent operators and engineers a long time ago. But many were not, and those that were have only been rigorously characterised and validated in recent years. Also the list which follow excludes the many improvements in process design and practice which have evolved through the efforts of mining companies, equipment suppliers, engineering companies and consultants.