

DISCUSSION

I. J. Stewart³

The authors are to be commended on the emphasis that their paper places upon the value of abrasives in stock removal operations, and for their determination of a simple method to calculate minimum-cost grinding conditions for a certain abrasive process. The purpose of emphasis, of course, is not necessarily related to the revelation of new ideas, but rather to the publicizing of any idea, new or old, in a manner that causes more people to notice, remember, and (presumably) use it. By relating Tarasov's data on abrasive machining to the well-known Taylor equation for the turning process, they certainly have increased the range of attention to and the likelihood of retention of a point that the abrasives industry has been trying with some diligence to make known.

The paper exhibits a refreshing disregard for one of the current fashions in engineering writing, that of discounting the criterion of engineering utility in favor of criteria based upon the complexity or novelty of approach, irrespective of the present or future utility of the final solution or conclusion.

The authors have noted properly in this paper that it pertains to a particular work-wheel relative motion, namely, that associated with vertical-spindle, rotary-table surface grinders. Some discussion of the generality of the results to abrasive processes as a whole is considered desirable. A contribution to this is contained in the next two paragraphs.

It is the writer's observation that this particular process exhibits the most unrealized roughing potential of all abrasive processes; it is, therefore, a very appropriate vehicle for the sponsor's purposes. However, a simple analysis of this process does not necessarily pertain to such widely used processes as cylindrical grinding, centerless grinding, or the other types of surface grinding (e.g., horizontal spindle, reciprocating table). The infeed rate (appropriately termed in this paper, downfeed) is not as predominant, in a practical sense, over other process variables in the economics of these processes as it is in the process studied by the authors. That is, these latter processes utilize much smaller wheel-work contact areas; therefore, wheel-work traverse time is necessarily much greater, and this must be explicitly accounted for in any study of processing time or economics. The addition of other process variables in the basic equation (2) would add much complexity of the graphical solution that forms the basis for the simplicity of this work.

Two elements of importance in the machining cycle are omitted from equation (3). These are the wheel mounting-and-truing cost and the work load-unload cost. The former is analogous to the tool-changing and resharpening costs involved in nonabrasive machining processes; it can easily exceed the wheel cost considered in the second term of equation (3). The latter cost is often significant in economic comparisons of alternative processes. Because both of these factors are independent of the infeed rate d , and hence would be eliminated in the differentiation use to obtain equation (6), the authors' purposes here would not be changed in any way by such a generalization of equation (3).

The optimum feed rate is not necessarily the minimum-cost feed rate as the authors state. In our economic system, all industrial optima necessarily relate only to maximum profitability. As engineers, we should take a broader professional view by more consciously recognizing the influence of marketing factors on our goals, i.e., our engineering optima. Only after consideration of the relationship of the profit derived from each increment of sales and the cost associated with making and distributing that sales increment can appropriate shop optima be defined. Clearly, any such definition will change with time. As an example, the minimum-cost criterion invoked by the authors is valid during the time that a corporation is operating below the break-even point.

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On the other hand, the criterion of maximum production rate, i.e., maximum removal rate in this case, is much more influential on total profit when this point is greatly exceeded, assuming the absence of market saturation factors within this range.

The authors' reference to the newness of the concept of gross stock removal by grinding should be clarified. The abrasive industry has been trying to sell this concept for more than three years, and production engineering courses at various colleges have been pointing this out for a much longer period. For example, at the University of Michigan, a large number of students have been required, as part of an upper-class laboratory course, to conduct an experiment comparing the processes of shaping, milling, and the type of surface grinding used by the authors; this experiment was first used there perhaps 15 years ago. No matter how fumble-fingered the students (of which this reviewer was one), the vertical grinder always came out well ahead as to speed of set-up, gross removal rate, and resultant surface finish. The abrasives industry has been very slow to realize and publicize the capabilities illustrated by such routine experiments. It is evident that the state of industrial advertising should not be confused with the state of engineering knowledge.

This long time lag in the commercial exploitation of such well-known engineering knowledge is most unfortunate for our economy vis-a-vis international competition. A number of companies have supported such R & D efforts as are represented in this paper. These companies are widely known because of their progressive R & D policies and, more significantly, have exhibited long-term growth rates well in excess of the average of other companies in their particular industries. However, from the standpoint of the national economy as a whole, equally good, if not superior, alternatives exist to proprietary R & D. The sponsorship of the present investigation by a trade association with no proprietary restrictions to its output, nor day-to-day competition to claim the attention of its engineering manpower, is notable, as is the fact that it was accomplished by research professionals. It in no way detracts from such useful studies as this to observe that they are routine for experienced personnel.

C. von Doenhoff⁴

The authors are to be congratulated for presenting a pioneering contribution of first-order magnitude in the vital subject area of abrasive machining. The following four comments are offered in an attempt to place this excellent analytical solution and its limitations into somewhat clearer perspective for the potential user of this method:

1 While it is true, as stated in the paper, that the cost associated with sparkout can be made essentially independent of downfeed rate by maintaining a constant time of sparkout, it nevertheless should be pointed out that this item may represent a large proportion of the total cost of removal, especially when d^* has a large value relative to the total downfeed distance. For example, at optimum d for the CS-configuration $d^* = 0.087$, indicating that the total downfeed distance of 0.100 in. required a downfeeding time of $0.100/0.087$ or 1.15 min, while sparkout time was controlled at 1 min. Since the abrasive cost was found to be 35 percent and the labor and overhead cost 65 percent of the removal cost excluding sparkout time, the total removal cost including sparkout time becomes

$$0.35 + 0.65 + (0.65)(1/1.15) = 1.56$$

or 56 percent greater than the removal cost calculated without including sparkout time.

For the R-configuration, the corresponding figures for the total cost of removal are

$$0.27 + 0.73 + (0.73)(1/1.59) = 1.46$$

or 46 percent greater than the removal cost calculated without including sparkout time.

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2 In attempting to draw additional conclusions from the authors' discussion of the small changes in d^* relative to changes in n when a "better" wheel is substituted, the potential user of this method must be cautioned that the validity of equations (18), (19), (20), and (21) is subject to the very severe restriction that $(\dot{\epsilon}^*/t)_1$ must be equal to $(\dot{\epsilon}^*/t)_2$. (Since these removal costs are equal under the terms of this restriction, the new wheel should then be called not "the better wheel" but perhaps "the more expensive and more efficient wheel.")

To indicate how different the results can become if this severe restriction is not fulfilled, it is necessary only to recall the results of the principal examples given in the paper. These illustrate how d^* can show a large change with a change in the value of n if $(\dot{\epsilon}^*/t)_1$ is not equal to $(\dot{\epsilon}^*/t)_2$. For a change in the value of n from 0.48 to 0.66, the value of d^* changed from 0.063 to 0.087 in. This represents a 37-percent change for both variables.

3 With reference to the authors' discussion of the degree of realism of the figure used for labor and overhead rate, the user of this method should be cautioned that the quantity " x " must be expressed in terms of either cents per contact minute or (preferably) cents per downfeed minute rather than in terms of cents per shift minute. Failure to do so leads to a falsely low value of d^* . The following illustration is given to demonstrate more clearly the meaning of these statements:

Let us assume that the conventional plant accounting procedures utilize a labor and overhead rate of 16.7¢ per shift minute. That means that the labor and overhead costs assigned to the work produced by the grinding machine must total up to $8 \times 60 \times 16.7 = \80 per shift. Let us further assume that the machine operator normally requires 50 percent of his eight-hour shift for nonproductive operations such as work set-ups and wheel changes, etc. The active time during which the wheel is removing metal then totals only 4 hr or 240 min per shift instead of 480 min. Since $d^* = 0.087$ ipm for the *CS*-configuration when $x = 16.7$ ¢ per min, it can be calculated that a total of $(240)(0.087)$ or 20.9 in. of metal will be removed per shift (neglecting for the present the effect of sparkout time). If we now calculate the labor and overhead charges which can be accounted for in end product from the grinder, we will find that they total only \$40 per shift, not \$80, because the machine is grinding for only 240 min per shift:

$$(20.9)(16.7/0.087) = 4000\text{¢} = \$40 \text{ per shift}$$

Consequently, it can be seen that the value of x , for use in the cost-optimum d calculations, should be set at 33.4¢ per minute, not 16.7 per min, in order to maintain the proper balance of debits and credits for the foregoing assumption of 50-percent productive time. The example given in the paper shows that when $x = 33.4$, the value of d^* becomes 0.117 ipm instead of 0.087 ipm. This indicates why it is essential for the quantity " x " to be expressed in terms other than cents per shift minute.

To be entirely correct, however, it is necessary to take sparkout time into consideration also. If we continue to assume that the sparkout time is controlled at one minute, then the value of x should properly be expressed in terms of cents per downfeed min-

ute. Assuming a downfeeding time of 1.15 min for an unspecified total downfeed distance, and a sparkout time of 1 min, then the correct value of x in cents per downfeed minute would be $(100/50)$ $(2.15/1.15)$ or 3.73 times the conventional accounting figure for labor and overhead rate in cents per shift minute. (This calculation assumes 50-percent total contact time including sparkout time as part of the contact time.) It can be seen that use of this value for x would result in a very much higher value for d^* .

In effect, this means that x is not truly independent of d , in the practical sense, and extreme caution must be exercised in setting the value for x .

4 This final comment concerns the necessarily limited scope of the solution presented in the paper. Two important limitations probably will not be immediately apparent to the potential user of this method. The solution presented in the paper does not take into account the differences in horsepower requirements between the *CS* and the *R*-configurations for the same wheel grading, and it does not take into account the possibility that, for equal power utilization, a harder grade of wheel could be used for the *R*-configuration than for the *CS*-configuration.

From Fig. 13 of the Tarasov reference, it can be determined that at the point $d^* = 0.087$ ipm for the *CS*-configuration, the net power required for grinding is approximately 110 hp, while at $d^* = 0.063$ ipm for the *R*-configuration, the net power required is approximately 65 hp. The effect of this discrepancy upon the usefulness of the solution given in the paper can be expressed in either of two ways:

(a) If the size of the drive motor on the machine were such that its maximum safe output corresponded to 75 hp of net grinding power, then the operator could not safely attain optimum performance in the *CS*-configuration, while he could easily attain the optimum performance in the *R*-configuration.

(b) If the size of the drive motor were such that its maximum safe output corresponded to 110 hp of net grinding power, then for the *R*-configuration a much harder grade of wheel could be used, up to the limit of grade hardness at which 110 hp was being drawn at the new, higher value of d^* for the harder grade on the *R*-configuration. Much more experimental information would be required in order to estimate how much harder grade could be used and how much larger the value of d^* would be. However, it is entirely possible that when this point of equal power utilization was reached, the *R*-configuration might produce a lower removal cost than the *CS*-configuration.

Authors' Closure

The authors wish to thank Messrs. Stewart and von Doenhoff for their comments.

The application of the techniques described in this paper will be quite different for processes other than vertical spindle surface grinding as Mr. Stewart suggests. The next process to be treated will be that of abrasive cut-off.

The remarks of Mr. von Doenhoff are useful in cautioning the reader against misuse of the ideas presented and in discussing some points beyond the scope of the paper.