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LOS ALAMOS SCIENTIFIC LABORATORY

of

THE UNIVERSITY OF CALIFORNIA

October 19, 1950 LA-1171

This document consists of 12 pages

THE BEHAVIOR OF HIGH EXPLOSIVES IN MACHINING OPERATIONS

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LA-1171

Washington Document Room	1 thru 4
J. R. Oppenheimer	5
Los Alamos Document Room	6 thru 23

THE BEHAVIOR

OF

HIGH EXPLOSIVES IN MACHINING OPERATIONS

Certain protective features are made a part of any modern, well-designed explosives fabricating, handling, or storage facility simply because the probability of accidental explosion is known to be greater than zero. Those details based upon the so-called Quantity-Distance Tables provide an example of such features. Many other details of construction and operating methods are chosen on the principle of calculated risk; in choosing the proper risk to design for under such circumstances, one does need to have an estimate of the likelihood of an accidental explosion under the conditions contemplated.

Design generally first responds to modest risk by dividing the total process (by distance and by barricades) into workable sub-units, each of which may be directly serviced by smaller numbers of persons than the total work force. As risk grows, these sub-divisions become smaller and "personnel limits" are reduced to their minimum usable values. Next, personnel may intervene directly only when absolutely required, and finally, operation is carried out completely by remote control. Overestimation of risk generally increases costs of installation, usually increases maintenance costs and depresses efficiency. Underestimation, of course, increases the costliness of accidents. When facilities are constructed for new types of operations on High Explosives, one is usually impelled to be over-conservative, making decisions which may be difficult later to undo. In connection with a rather considerable current construction program for explosives machining facilities, it seems appropriate to review both the H.E. machining experience of the past six years, and certain machining experiments which have been conducted here under exaggerated conditions. This is especially important because machining of High Explosives by rather conventional metal-working techniques is apparently viewed by the casual observer as an extremely hazardous operation; the following report strongly indicates, on the contrary, that for the explosives in question it is an exceedingly safe one.

I. Past Experience

Shaping of Composition B and Baratols* (Barium Nitrate-TNT mixtures) with machine tools has now been practiced for the order of six years. The various machine operations have not been alike in detail, but have involved sawing, turning in lathes, cutting with contour (or "fly") cutters, and cutting with normal milling cutters. These operations have quite generally been performed with tool and work flooded by water jets, and with linear tool speeds at or below 70 ft./min. The tools themselves were normally made of tool-steel, and kept well sharpened. Now the two explosives are certainly not equally sensitive, nor were all the types of machining equally severe

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*These have contained 71, 73, and 76% Barium Nitrate at various times.

or of equal time duration, so that the total record is certainly not that of statistically homogeneous experience. Nevertheless, some importance does attach to the fact that to date roughly 1,600,000 such separate operations have been carried out without charring, ignition, or detonation. It seems pointless to calculate the maximum probabilities of "reaction" compatible with this experience at various confidence levels, because of the heterogeneous nature of the experience. One must, nevertheless, conclude that this average type of operation, far from being extremely hazardous, seems to present no more than roughly one chance in a million of a specific explosive accident, and could be much safer.

II. Accelerated Experiments

Though the above experience does provide some information, it is not able to answer two questions which are pertinent in assessing the hazard of the machining operation. The first of these may be framed as follows: Let us assert that it is at least conceptually possible to consider a "severity" parameter associated with a machining operation; this will certainly involve linear tool speed, rate of feed, nature of tool, sharpness of tool, extent of water-flooding of work, contamination of work by foreign objects, etc. Then, in principle, there must exist for each type of explosive a curve of probability of reaction as a function of "severity" (rather like the impact machine curves of probability of explosion as a function of drop-height), which is roughly cumulative normal in

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nature. Actually the "severity" variable should be so expressible that the curves for one explosive can be rather simply transformed into one another; thus the name of the explosive could also be included in the "severity" parameter, and our consideration is thus focussed on one curve. Past experience as cited in Section I thus affords us the information that, at past operating levels of "severity" the curve had not risen to higher than roughly 10^{-6}, and could be much lower. What is the further course of this curve for greater "severity" of machining conditions? This question is of two-fold interest. Without knowledge in this matter one cannot be sure but that some apparently minor change in "severity" - e.g., a small increase in allowed tool-speed, a slight increase in RDX content of a Cyclotol, a new tool-type, etc., might not greatly increase the hazard.*

The second question concerns the nature of the "reaction" mentioned in the previous paragraph. Will this be prompt detonation of the stock, or leisurely burning, or something intermediate? In the absence of answers to this second question it is likewise difficult to assess or protect against the real hazard.

In order to provide at least some feeling for the answers to these two questions, if not completely to answer them, a series of

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*There is, of course, really a further interest implied here, viz., in the actual framing of the "severity" variable, but, as will be seen, no progress in this direction has really been made.

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experiments in machining at higher [illegible] levels has been conducted, which will now be described.

1. Experimental

These accelerated experiments were performed by remote control with a Cincinnati-Bickford 24" vertical drill. The machine is equipped with a 6" diameter, four-bladed, radial, vertical cutter, and is driven by a 5 H.P. explosion-proof electric motor. This cutting tool is of a type frequently used for production H.E. machining, and has four tool-steel blades set at 90° one to another. The effect of such tools is felt to be more "severe" than of "point-type" tools, because larger areas of material are cut at once (i.e., the "hot spot" is larger). The sample is held under the cutting head by a device which permits ejection from the machine in case of burning, and is surrounded by a dust-screen down whose sides water-spray washes to carry away dust and chips, but in a fashion such that water does not come in contact with the stock or the cutter. The operation is viewed from the control station by a television system.

All experiments were performed without water on the work (in contrast to production machining). Maximum linear tool speed was varied by varying shaft speed and piece-diameter. Tool feed rate was separately varied, and in some cases the cutter blades were dulled by filing their edges. The effective severity of the conditions was also varied by machining several explosives and by machining samples containing foreign inclusions. Tests were begun on the least sensitive materials at linear tool speeds around 150 ft./min.

and a feed rate of 0.011 in./rev. Speed was then stepwise increased to the maximum of which the machine was capable (this corresponded to 1160 ft./min. on a 3" diameter sample). When maximum speed was reached, feed was increased to 0.043 in./rev. Next a cutter intentionally dulled by filing the blade edges was used at maximum speeds. Runs were also made at maximum speed but minimum feed of 0.005 in./rev. to increase exposure time obtainable with a given piece. Tool speeds in excess of 1160 ft./min. were obtained with larger diameter charges. At the highest speeds with dull cutters the 5 H.P. motor stalled, so that more severe continuous conditions were not achievable. A few Composition B charges were, however, prepared with intentional foreign inclusions, and machined at various rather high speeds. Details of the various experiments are summarized in Tables I and II.

Table I: Experimental Details: Uncontaminated Explosives

Explosive	Max. Linear Tool Speed (ft./min.)	Feed (in./rev.)	No. of Pieces Cut	Blades
Baratol 76	1160	0.011-0.034	5	sharp
	1160	0.043	2	sharp
Composition B	1160	0.011-0.034	3	sharp
	1160	0.043	4	sharp
	1160	0.043	1	dull
	1400-1820	0.011-.043	1	sharp
	2240	0.043	4	sharp
	1650	0.043	1	dull
	2240	0.043	3	dull
Cyclotol 70/30 + 1% wax	1160	0.011-.043	2	sharp
	1160	0.005	2	dull
	1160	0.043	7	sharp
	1160	0.043	4	dull
Cyclotol 70/30 No wax	1160	0.005	2	dull
	1160	0.043	6	sharp
	1160	0.043	3	dull
Pentolite 50/50	1160	0.011-0.034	2	sharp
	1160	0.005	1	sharp
	1160	0.005	1	dull
	1160	0.043	4	sharp
	1160	0.043	4	dull
	1400	0.043	1	sharp
	1400-2290	0.043	1	sharp
	1760	0.043	1	dull
	2240	0.043	3	sharp
	2210	0.043	1	dull

Table II: Experimental Details; Composition B with Foreign Inclusions

Inclusions	Max. Linear Tool Speed (ft./minute)	Feed (In./rev.)	No.	Blades
Aluminum - 1" bolts, nuts; 1/4" screws	550	0.011	1	sharp
Brass - 1" bolts, nuts; 3/4"-1/4" screws, washers	1410	0.011	1	sharp
Glass - Glass wool, crushed pyrex tubing	1885	0.011	1	sharp
Steel - 1" nuts, bolts; 3/4-1/4" screws and washers	2120	0.011	1	sharp
Rocks - 1/8-1/4" dia. gravel	2120	0.011	1	sharp

2. Results

In no case, among the above 74 tests, did either detonation, burning, or even charring occur. In some of the more violent circumstances, the charge itself was broken by the forces involved, and (especially with dull cutters) surfaces were sometimes rough and scored by chatter-marks. Cutting Composition B containing steel or gravel did produce enough heat to melt some TNT, and in the latter case (gravel) an odor (perhaps of oxides of nitrogen or other decomposition products) was noted.

3. Discussion

These results are, in a sense, frustrating. They provide no answer at all to our second question (i.e., the nature of the "reaction" to be expected in a machining accident). Since no reactions could be obtained, one also is left with no real answer to the first question either, except that under average conditions of these experiments, which are greatly more severe than those employed in production, the probability of reaction has still remained too low to have produced one reaction in 74 trials; moreover, even under the most severe conditions we have been able to provide (apparently cutting through steel and rocks embedded in Composition B) no more than local melting and a suspicion of odor of decomposition products could be produced.

4. Conclusions

Although the number of these exaggerated experiments is limited, the extent of the exaggeration seems very great indeed.

There seems no practical value at all in production use of tool speeds above 200 ft./sec. Dry machining is not contemplated, since wet operation serves the quite separate purpose of keeping down toxic dusts and cleaning the work of chips. Explosives greatly more sensitive than Composition B are not contemplated for use because of the general hazard they would introduce into both manufacture and field handling. One must therefore conclude that the excellent safety record established in machining operations (Sec.I.) does have real meaning and that no forseeable circumstances are likely to change this apparently very safe operation into a sensibly hazardous one (i.e., small changes in tool types, tool speeds, explosive compositions, etc.). It is also suggested that the chance of explosion under "normal" conditions may be much less than one in a million.

5. Future Plans

It is now proposed that experiments of this type be carried out on any new explosives proposed for machine fabrication, but that further attempts to produce information of more basic nature be planned in a different manner. It seems wiser to attempt very high-speed cutting with point-tools in equipment built especially for this purpose.

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