INVESTIGATION INTO RESEARCH DATA ON HE SENSITIVITY TO IMPACT (# 264)

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The paper presents data on the explosion probability versus drop height of load obtained in drop weight tests of HE. Using two different designs of impact setup, the tests were performed for RDX, HMX and plasticized HMX- based HE. The test data are in contrast to the common thinking as they show the relationship between explosion probability and the drop height to be, at least in a few cases, in disagreement with Gaussian law. There may be a portion in this curve, where the explosion probability is virtually independent of the load drop height. This consideration is what one should keep in mind in order to avoid gross errors in the HE sensitivity characterization.

INTRODUCTION

It is of great scientific and applied interest to study the impact sensitivity of explosive materials using laboratory methods. At present, many methods have been developed and are currently used to look into this property. From our knowledge of the existing methods, they all have a common limitation, which is large variation among the data from parallel tests. This may occur, in particular, due to wrong selection of the test load (such as load weight and drop height). We have established a relationship of explosion probability to drop height of load for several HE materials. It has been observed, that given the behavior of such curve is taken into account, it would be easier to provide the test conditions that allow smaller variation among the parallel test data.

EXPERIMENTAL RESULTS

We used in our study two different impact setups – Unit 1 (figure 1) [1] and a Paper-Sleeve Unit (Unit BM-M, figure 2) [2].The HE weights were 0.05g for Unit 1, and for Unit BM-M – 0.1g. In the latter case, the weight of HE had an addition of quartz sand at 10% by mass with particle size of 0.25 to 0.35mm.

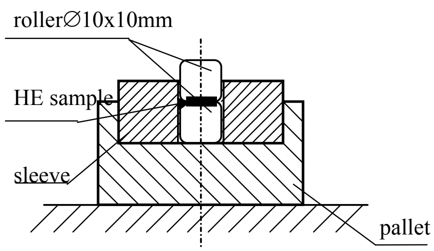


FIGURE 1. UNIT 1 FOR HE IMPACT SENSITIVITY TESTS

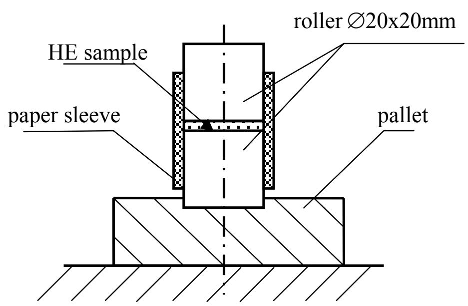


FIGURE 2. UNIT BM-M FOR HE IMPACT SENSITIVITY TESTS

Experimentally, the HE sample was impacted with a dedicated setup using the drop of load. The drop height of load was 250 mm. In order to ensure effective testing of the HE materials having different sensitivities the load weights of 2kg and 5kg were used.

In Russia, the more widely accepted method is which is basically used to determine the relative explosion frequency (probability) from a run of 25 tests [1].

Our colleagues abroad employ impact testers, which are rather different and there is quite a variety of these.

More frequently, they use as quantitative measure of impact sensitivity the drop height of load, for which the explosion probability equals 0.5 (H-50), and in most cases it is measured by "up-down" method [3].

All methods in use are similar in their main details. Thus, their common and very important limitation is large variation of the data resulting from parallel tests. In particular, when the relative explosion frequency is determined with the above- mentioned method that we address, the variation may be up to 40% and larger [4].

Tables 1 and 2 summarize H-50 measurements using "up- down" method for several HE materials.

TABLE 1. H-50 VALUES FOR RDX (LOAD MASS M=5kg, UNIT 1)

Test run No.	1	2	3	4	5	6	7
H-50 (mm)	132	135	150	158	162	163	189
Test run No.	8	9	10	11	12	13	
H-50 (mm)	212	232	236	259	271	280	

H-50= 198.5mm S=52.7mm k=S/H-50=0,265

S – standard deviation

k=S/H-50 – coefficient of variation

TABLE 2. H-50 VALUES FOR HMX (LOAD MASS M=2kg, UNIT BM-M)

Test run No.	1	2	3	4	5	6	7	8	9
H-50 (mm)	125	159	167	179	185	192	205	328	333

H-50= 208mm S=73.1mm k= 0.351

Most obviously, such data from parallel tests as these values cannot be regarded as satisfactory.

One essential problem in characterizing the HE sensitivity to impact is reasonable selection of the level of load upon the test sample (selection of the load mass or drop height). Thus, an important consideration here is that 0% and 100% for relative explosion frequency can not be informative values, so that once such data are observed, further tests must be performed at other load levels.

We believe that reasonable selection of the test load value as well as quantitative assessment of the impact sensitivity are impossible without considering the pattern of relationship for explosion probability versus the load upon HE test sample (P=f(H) relationship).

Most researchers assume this relationship includes a curve that basically shows the explosion probability to grow monotonically with higher load levels. Moreover, there have been statements in the literature that this relationship depends upon normal distribution, or Gaussian, law, thus looking as shown in figure 3 [5]. To the best of our knowledge, L.C.Smith, a noted authority in sensitivity studies shares this concept too. However, no detailed information is available with us that tells about the experimental procedure specifically and, most importantly, statistical confidence of the observations that were used as the basis to make conclusions accordingly.

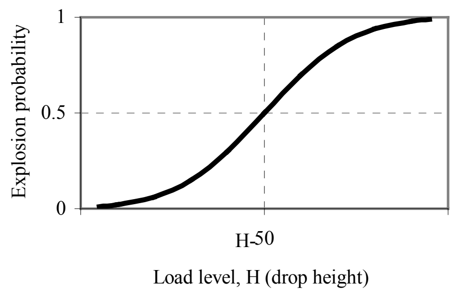


FIGURE 3. PROPOSED P=f(H) RELATIONSHIP

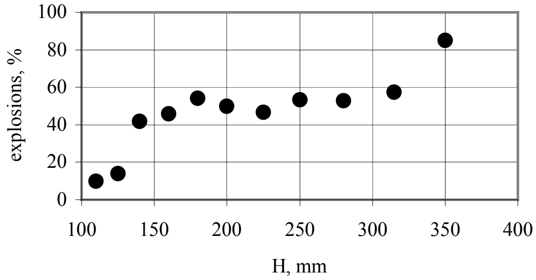
Because the behavior of relative explosion frequency as a function of the impact load, P= f(H), is very significant for consideration, it motivated a specific research effort.

Thus, there were tests performed that used two different types of impactor units, and with the aim in view to provide as varied strain conditions as possible for the test sample. For each HE material, the greatest possible number of tests was made with both impactor units in order to achieve statistical confidence of the resulting data. The units that were used in the tests are schematically shown in figures 1 and 2.

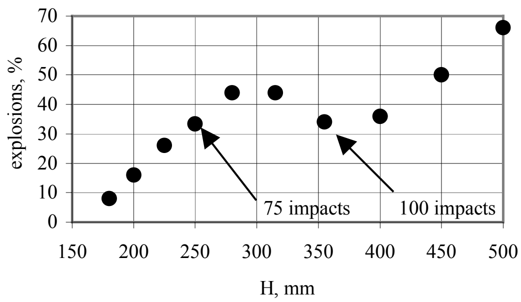
The following HE materials were used in the tests: RDX, HMX, and plasticized HMX- based explosive.

For each of the curves below, we had conducted from 500 to 1000 tests (at least 50 impacts per experimental point).

As a result of this study, the data are as given in figures 4 and 5.



a)

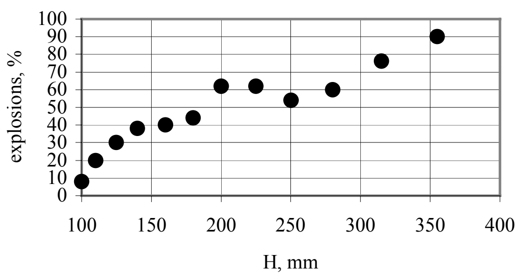


b)

FIGURE 4 . RDX EXPLOSION PROBABILITY VERSUS DROP HEIGHT OF LOAD

a) load mass M=5kg Unit 1

b) load mass M=2kg, Unit BM-M



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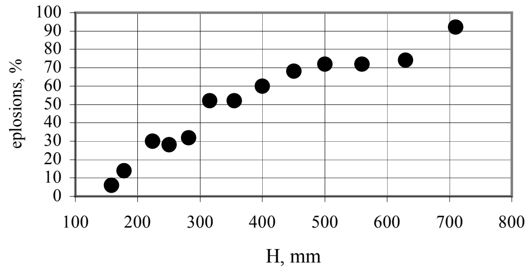

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FIGURE 5 . EXPLOSION PROBABILITY FOR
a) RDX
b) PLASTICIZED RDX
VERSUS DROP HEIGHT OF LOAD MASS M=2kg IN UNIT BM-M CASE.

The following can be observed from the test results. In the great most of our experiments, there is rapid enough rise of the relative HE explosion frequency initially with increase of the drop height of load, and then this rise is to become slower as the height is going up further. There are some cases where the relative HE explosion frequency stops to grow altogether. It would not continue to rise until the drop height of load has reached some ultimate value. In other words, the derivative does not show monotonic increase on the initial portion of P= f(H) curve , and after reaching some point of maximum it does not go down monotonically, thus not forming the well-known Gauss curve.

We believe the following should be essentially mentioned:

- the cited P(H) relationships have been obtained for different HE;

- the tests were different from each other in conditions (different impact unit types, load mass);

- the data have high statistical confidence (at least 50 impacts per experimental point).

Based on the considerations above, one can suggest that the P= f(H) curve follows Gaussian law at least not in every case.

In this context, it has to be investigated why the increase of load level for HE sample does not make the relative explosion frequency grow on some portion of the P= f(H) curve.

A.F.Belyaev was the first to take notice that the P=f(H) curve may show such behavior when he was conducting tests on the ternary mixtures of ammonium nitrate, TNT and inert fuel [6]. Our test data are the result of experiments on HE, whose properties are essentially different than those of the above materials, and with different impact devices. This is a suggestion that these observations are not any kind of abnormal phenomena due to the infrequent coincidence of some factors, but they reflect the actual properties of HE.

With the allowance for A.F.Belyaev's findings and based on the vast amount of more recent experimental data, such behavior of the relationship P= f(H) takes place because of the following.

The probability of explosion upon impact depends on two factors, and they are

- probability of the decomposition site (hot spot) initiation:

- probability of the reaction developing from initial site through the entire or much of test HE.

Before it has reached the phase where we can detect it from the sound effect, the explosion development is determined by the two factors above, which are in competition with each other. As the drop height of load increases, this leads to more hot spots and to their temperature and size growing too, thus causing the explosion probability to go higher. Moreover, increase of the drop height also results in larger pressure upon the test sample and its higher density as a consequence. This is an effect that involves more difficult conditions for the explosive transformation to proceed from hot- spot to explosion phase. Therefore, it results from combined effects of the two factors that the explosion probability should grow slower with increase of the drop height of load.

Initial portion in P=f(H) curve is dominated by the latter factor, where the hot spots are few but the conditions are good for explosion to develop. However, behavior of the final portion of the relationship is more dependent on the former factor, i.e. the larger drop height of load allows initiation of the hot spots having sufficient properties for explosion to develop even though the conditions are relatively unfavorable

The following should be pointed out as important implication of the test observations.

For the tests of RDX (with both Unit 1 and Unit BM- M), plasticized HMX (Unit 1) and fine grained HMX (Unit BM- M), the segment where the explosion probability is ~0.5 shows the explosion probability to be very little dependent on the drop height of load. In particular, it is evident from the data given in figure 4, that the explosion probability would keep virtually unchanged at about 0.5 for the drop heights of load in the range from 180 to 320 mm. Therefore, it is questionable if H-50 value is applicable as measure of sensitivity at least in this particular case. To support this statement, there are H- 50 data obtained in the RDX and HMX tests using "up- down" method (see Tables 1 and 2), which are hardly to be recognized as satisfactory.

Thus, it is impossible for Unit 1 to use the load of 5kg mass in determination of H-50 value for RDX, and the same argument can be referred to the use of Unit BM- M and the load of 2kg mass with respect to HMX case.

However, the case is different with H-50 characterization of plasticized HMX, for which the relationship P= f(H) is provided in figure 5. Here, the relationship P= f(H) clearly shows a downward segment for the relative frequencies of 50%. The H- 50 values found for this case are summarized in Table 3.

TABLE 3. H-50 VALUES FOR PLASTICIZED HMX (LOAD MASS M=2кг, UNIT BM-M)

Test run No.	1	2	3	4	5	6	7	8
H-50 (mm)	299	317	321	331	332	350	351	386

H-50= 335.7mm S=26.5mm

k=S/H-50=0,079

As it should be expected, this case is in line with the earlier assumptions and the variation of H-50 has been much smaller here.

CONCLUSIONS

1. It is essential for the impact sensitivity study of HE that allowance should be made for P= f(H) relationship in selection of the test procedure, the quantitative measure of sensitivity and the impact loading conditions.
2. The sensitivity test methods that exist call for improvements, which also include providing these methods with a sound scientific basis.

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