RADIOGRAPHIC SENSITIVITY OF FLAW DETECTION IN SOLID ROCKET PROPELLANTS

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The sensitivity of flaw detection with x-ray radiographic methods is investigated here qualitatively in case of cast double base and cast composite propellants and for air pockets it is found to be 1·5 and 0·9 percent of the web respectively. General guidelines for the inspection of sustainer charges have also been laid down.

The presence of cracks, voids, air pockets and similar flaws in propellant grains seriously affect the performance during firing. The detection of such flaws by the non-destructive testing methods is therefore essential to ensure a satisfactory performance. Ultrasonic flaw detection (U.S.F.D.) methods do not reveal the exact nature of flaws in case of extruded and cast double base (E.D.B. & C.D.B.) propellants. Further USFD is not suitable for composite propellants for want of a proper medium. Thus X-ray radiographic method for flaw detection is a better alternative here.

Radiography is concerned with the production of radiographs—photographic image produced by X-rays or by ionising radiation—in general. The differential absorption due to the variation in thickness and density of the material, the ability to penetrate matter due to short wave lengths and the linear propagation provide the fundamental basis of radiography. The presence of flaws such as cracks, air pockets, foreign-matter etc. in the specimen interrupt the continuity of the material and give rise to thickness changes or produce local variations in its density. Such flaws create local differences in the intensity of the radiation transmitted by the specimen. Thus the radiograph gives the information regarding the internal structure of the specimen. The manner in which the film records these variations governs the sensitivity of the radiograph. The sensitivity of a radiograph is an indication of its ability to reveal flaws or density changes in the specimen being examined.

However, for the flaw to be detectable on the radiograph it has to have certain minimum dimensions i.e. minimum thickness change, below which it goes undetected. This limitation on the dimensions (thickness change) of the flaw depends on : (1) Orientation of the flaw in relation to the X-ray beam, (2) Details of the radiographic technique employed viz. film contrast and film grain size, film-focus distance, intensifying screens etc., (3) Total thickness of the specimen, (4) Position of the flaw through the thickness of the specimen. To estimate this limiting dimension of the flaw which could be detected by the radiographic inspection, the use of penetrameter, also known as image quality indicators (IQI) is made. The penetrameter[1] is a device for measuring penetrating power of a beam by comparing transmission through various absorbers. Standard penetrameters for the radiography of metallic specimen are readily available. But suitable ones for solid rocket propellants are not commercially available.

Since the nature of flaws in the case of propellants is trapped air (air pockets) invariably, artificial flaws were introduced in the propellant grains by drilling holes to estimate the minimum thickness change that can be detected. It is expressed as the percent ratio of flaw diameter to the web thickness of the specimen.

EXPERIMENTAL

For the present investigation philips' MG 150/300 Industrial X-ray Unit has been used.

The details of the propellant samples are as follows :

(1) C.D.B. propellants (nitro cellulose and nitroglycerine base) solid cylinder of 147 mm diameter and 169 mm height, density being 1·56 gm/cc

(2) Composite propellant (Polyurethane base)—solid cylinder of 172 mm diameter and 155 mm height, density being 1.60 gm/cc

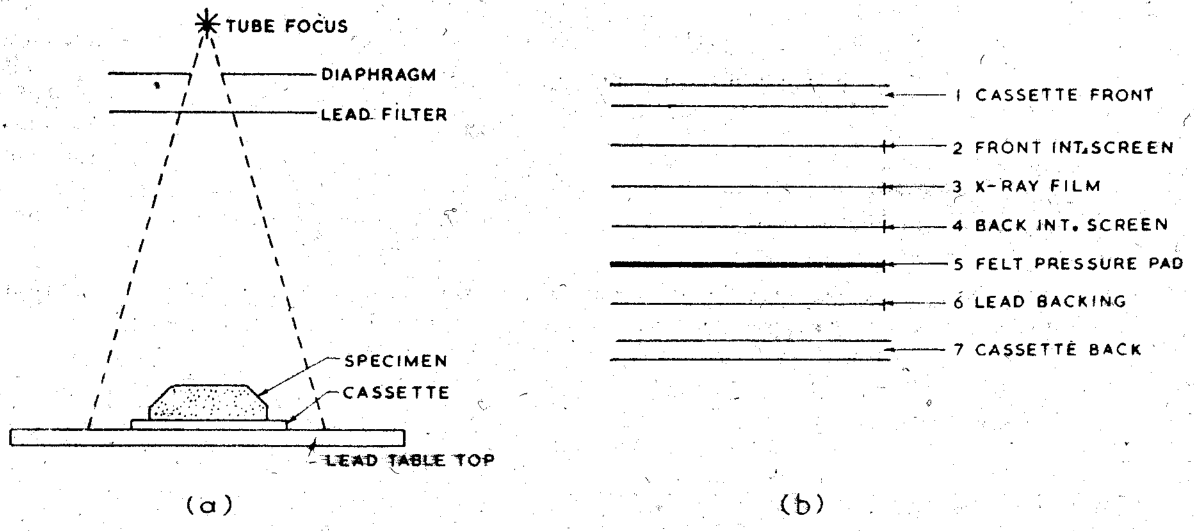

Fig. 1—(*a*) Typical lay-out for radiographic inspection, (*b*) Cross section through the film cassette.

The specimen under investigation were C.D.B. propellant of length 170 mm and diameter 147 mm and composite propellant of length 150 mm and diameter 172 mm which were selected after the initial 'screening' for any visible defects or flaws. Then the approximate accelerating potential (KV) and the current (mA) necessary for various propellant thicknesses were found out. Radiographs with different orientations of the specimen before introducing the artificial flaws were first taken to detect serious flaws introduced

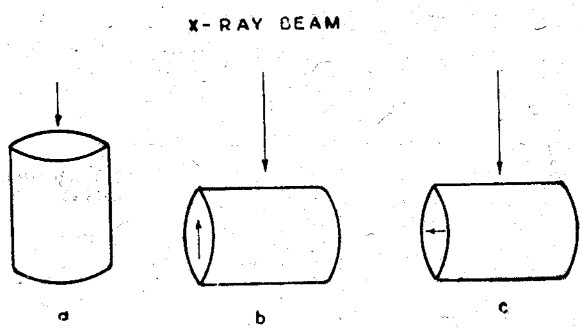

Fig. 2—Specimen orientations for inspection.

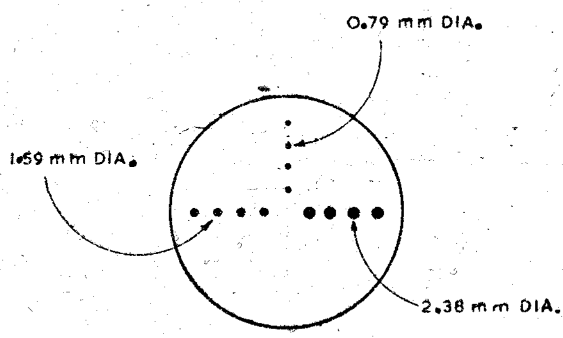

Fig. 3—Arrangement of artificial flaws.

initially during the processing of the charges. A typical lay-out for the radiographic inspection is shown in Fig. 1, and in Fig. 2 different orientations of the specimen for inspection are shown. Then holes of different diameters 0·79, 1·59 and 2·38 mm (1/32, 1/16 and 3/32 in.) parallel to the axis of the specimen were drilled to a depth of about 15 mm Fig. 3. Radiographs of the specimen in orientations b & c (Fig. 2) were taken with different voltage settings and the same current and exposure timings.

The X-ray films used were Agfa Gevaert's Structurix D7, a fairly fast and contrasty fine grain film. For the development, Agfa Gevaert's developer T-230 and the fixer 'X-ray Fixadon' were used. The developing time, rinsing time, fixing time and the washing time were the same for all the films.

RESULTS AND DISCUSSION

Results are given in Tables 1 & 2. It is seen from the tables that the sensitivity of flaw detections is calculated numerically in terms of the detectable hole diameter as a percentage of the web i.e. the propellant thickness traversed by the X-rays. Thus it can be said that cracks, air pockets, etc. of about 1·5% of the web in case of C.D.B. and about 0·9% of the web in case of composite propellants could only be detected and any flaw below this could not be detected. (The 0·79 mm diameter flaws in case of C.D.B. are not included in the table, as they did not reveal themselves on the radiographs. Similarly the 2·38 mm diameter flaws in case of composite propellants are not included in the table, as they were obviously detectable on the radiographs due to larger diameters).

The investigation is somewhat qualitative as the 'detectability' is made by the naked eye. Quantitative and more accurate measurements could be made with the help of Film Densitometer.

TABLE 1

'CDB' PROPELLANT

Tube parameters			Hole-diameter 'd' (mm)	Web-thickness 't' (mm)	Flaw sensitivity =(d/t) ×100 (%)
Voltage (KV)	Current (mA)	Exposure (min)			
85	3	1	1·59	105	1·5
85	3	1	2·38	135	1·8
90	3	1	1·59	125	1·3
90	3	1	2·38	140	1·7
95	3	1	1·59	135	1·2
95	3	1	2·38	145	1·6

Average flaw sensitivity = 1·5%.

TABLE 2

COMPOSITE PROPELLANT

Tube parameters			Hole-diameter 'd' (mm)	Web-thickness 't' (mm)	Flaw sensitivity =(d/t) ×100 (%)
Voltage (KV)	Current (mA)	Exposure (min)			
115	6	1	0·79	125	0·6
115	6	1	1·59	145	1·1
120	6	1	0·79	125	0·6
120	6	1	1·59	160	1·0
125	6	1	0·79	Insufficient Contrast	
125	6	1	1·59	160	1·0

Average flaw sensitivity = 0·9%.

The voltage required for a certain thickness of propellant has been determined. It has been seen that to inspect a sustainer charge, the inspection has to be carried out in two parts. In the first part, the outer or peripheral region has to be examined with a suitable voltage depending on the propellant. In this case the core region cannot be examined as it gets under exposed. In the second part, the voltage is increased suitably so that the core region is properly exposed but the peripheral region gets over exposed. In both the parts minimum two orientations-one turned through 90°, of the specimen are necessary for a thorough examination. In this way a complete inspection for flaws could be carried out.

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