Ballistic Properties of Propellant Containing Nitropolyurethane

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Introduction

In previous paper1), the physical properties of some nitropolyurethane elastomers have been studied. In this paper we examined the ballistic properties of the propellant made with the nitropolyurethane which incoporated positive oxygen within the binder structure.

The polyurethane-ammonium perchlorate (propellant A) and the propellant containing the nitropolyurethane (propellant B and C) were prepared, and their physical and ballistic properties were determined.

Experimental

Raw Materials

Polyglycidyl nitrate glycol was prepared by the polymerization of glycidyl nitrate and then water was evaporated in vacuo at 120℃. Polypropylene oxide glycol, tolylene diisocyanate (an 80 : 20 mixture of the 2,4- and 2,6-isomers), and trimethylol propane were obtained commercially. Ferric acetyl acetonate was used as a curing catalyst. Ammonium perchlorate was supplied by Daicell Co., Ltd.

Size of Grain

The used propellant grains were internal-external burning type and size of the grain was shown in Fig. 1.

The tensile properties of the grains were determined on the basis of the Japanese Industrial Standard (JIS-K-6301) : Dumb-bell shaped Pattern No.3 test pieces were used.

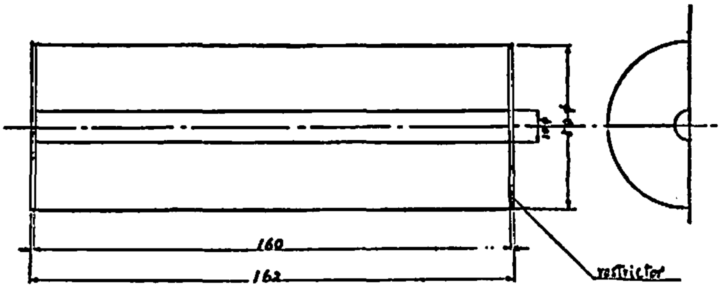

Fig. 1 Size of Grain

A Shimazu autograph tensile tester (Model IS-1500) was used to measure the tensile properties : tensile strength and elongation measurements were conducted at an extension rate (initial) of 500mm/min.

Results and Discussion

The compositions of these propellants are given in Table 1 along with the physical properties. The chemical formulation of all propellants used in the present work was

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Table 1 The composition and physical properties of propellants

Propellant	Composition of propellant	Composition of binder	Maximum stress at 20°C kg/cm²	Maximum strain at 20°C, %
Propellant A ; N_0-1	(standard) AP 75parts binder 25parts Al 7parts	polyurethane	16	37
N_0-2	ditto	ditto	—	—
Propellant B ; N_0-3	ditto	polyurethane 90parts nitropolyurethane 10parts	23	33
N_0-4	ditto	ditto	—	—
Propellant C ; N_0-5	ditto	polyurethane 70parts nitropolyurethane 30parts	27	21

identical. All propellants were processed well with the usual composite solid propellant processing equipments. However, the propellants with binders containing over 50% of the nitropolyurethane were not processable because of evolution of gas during curing.

A number of small rocket motors (Fig. 2) containing the propellant grains shown in Table 1. were made and tested over a pressure range of 20-70kg/cm² (Fig. 3). The typical combustion pressure and thrust-time curves of these motors are shown in Fig. 4 and 5. The observed values for burning rate and specific impulse are summarized in Table 2.

The combustion pressure-time curves of these motors should be generally neutral from a view point of grain configurationn and also

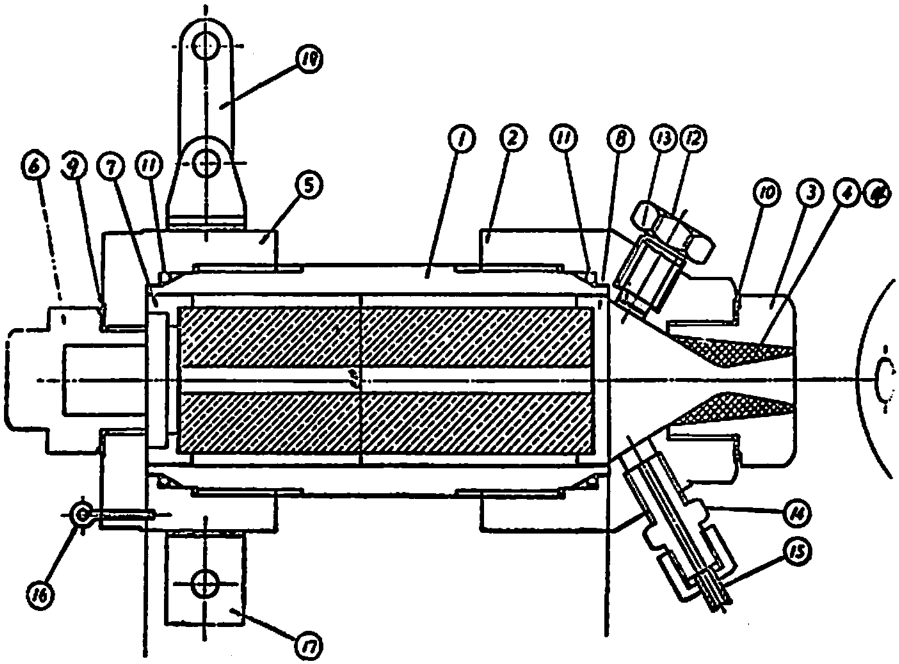
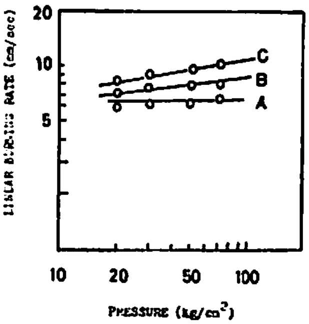
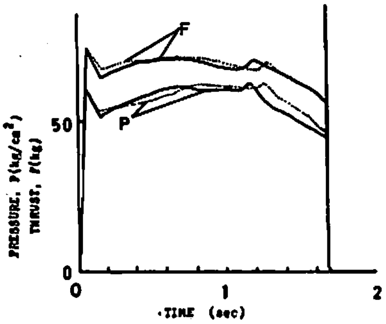


Fig. 2 Rocket Motor



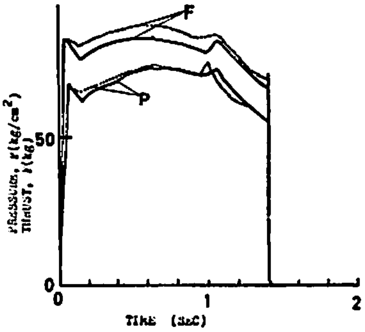
A; propellant A, B; propellant B,
C; propellant C

Fig. 3 Burning rate vs. combustion pressure



——; N_0-1, ……; N_0-2

Fig. 4 Pressure (P) and thrust (F) vs. time traces for propellant A



——; N_0-3……; N_0-4

Fig. 5 Pressure (P) and thrust (F) vs. time traces for propellant B

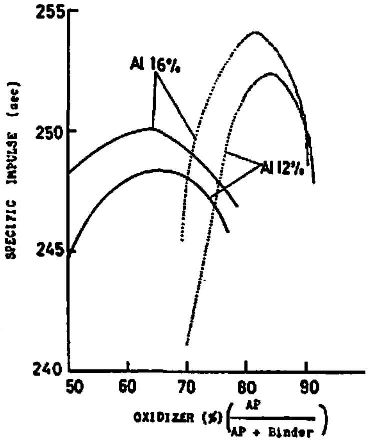
a given set of ballistic conditions. However, two peaks appeared in first and final burning region, and simultaneously, these curves appeared to be convex having a maximum in the middle range of firing. These maximums were probably caused by 1) the retardation of ignition, or 2) radiation from the heated motor case to the charge, raising its temperature. It was recognized from the observation of flame spreading with a transparent motor that the time from ignition to steady combustion 0.1 second. Therefore, the latter seems more reasonable.

Table 2 Ballistic properties of the propellants

	Propellants				
	N_0-1	N_0-2	N_0-3	N_0-4	N_0-5
	(standard)		(propellant B)		(propellant C)
Mean combustion pressure kg/cm²	50	50	50	50	50
Burning rate, mm/sec	6.5	6.5	8.0	8.0	9.5
Burning rate increase over standard, %	—	—	23	23	46
Specific impulse (observed) sec	213	202.2	191.7	197.3	—
Weight of propellant, g	536	537	535	533	535

The values of average burning rate were about 6.5, 8.0 and 9.5mm/sec for propellant A, B and C respectively under the pressure of approximately 50 atm. The burning rate of the polyurethane propellant was markedly by incorporating nitro groups in the polymer main chain, as observed in propellant B and C. It appears that the introduction of the nitro group in the polymer makes an increase of propellant burning rate.

The experimental values for specific impulse of propellant A and B were compared with theoretical values for polyurethane-ammonium perchlorate propellant and nitropolyurethane-ammonium perchlorate propellant. The theoretical specific impulse was computed by using thermodynamic equation[2] and the computed specific impulse vs. the propellants compositions are shown in Fig. 6. The attainable maximum specific impulse of nitropolyurethane-ammonium perchlorate propellant is slightly lower than that of polyurethane-ammonium perchlorate propellant and the optimum formulation of the former shifts to lower composition ratio of ammonium perchlorate. while the specific impulse of polyurethane-ammonium perchlorate propellant depends intensively upon the oxidizer concentration, nitropolyurethane-ammonium perchlorate propellant is not so sensitive to oxidizer concentration. This behavior is a character of the propellant made of oxidizing binder.



……; polyurethane, ——; nitropolyurethane,
the chamber presure; 50atm
the exhaust pressure; 1atm

Fig. 6 Isp vs. the composition of oxidizer

As estimated from theroretical specific impulse, the experimental values for specific impulse of propellant B having oxidizer of 75% were slightly lower that of propellant A, though the accuracy was poor.

Summary and Conclusion

Polyurethane-ammonium perchlorate propellant (propellant A ; standard) and propellant containing nitropolyurethane (propellant B and C) were prepared. The ballistic properties of these propellant A, B and C, mainly burning rate, were measured with small rocket motors.

The burning rate, theoretical and experimental specific impulse and some mechanical properties of propellant containing nitropolyurethane were compared with those of standard propellant ; the results were 1) the burning rate of the former increased in proportion to the amount of the nitro group 2) the specific impulse of the former did not intensively depend upon the oxidizer content.

References

1) S. Abe and K. Namba, J. Appl. Polymer Sci., 12, 1792 (1968)

2) A. J. Stosick, Ind Eng. Chem., 48 722 (1956) : T. L. Smith, ibid 52, 776 (1960)