On the Errors of a Time Counting System for Use in Experiments with a Shock Tube*

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Abstract

A time counting system for use in a shock tube having an accuracy of 5 counts of 1 Mc/s pulses are made, and the process of improvement of its accuracy is described.

The development of detached shocks ahead of 180° and 10° wedge sections in the transonic region is experimented with the shock tube.

1. Introduction

With a shock tube, the author has made experiments on the development of detached shock waves ahead of obstacles in the transonic region. For this purpose a shock tube and measuring apparatuses were made, and some of the results obtained with them were already reported.^{1),2),3)} In the transonic region, however, slight changes in Mach number show a large difference in the test results. For examples, when the Mach number changes by 0.01, the errors in the distances of shock waves ahead of obstacles are of the order of 10 per cent of s/t for $M=1.15$ and 30 per cent for $M=1.05$. (symbols are illustrated in Figs. 1 (b) and 6)***.

Therefore the accuracy of the measurement of shock velocity in a shock tube gives a very serious influence upon the precision of the experimental results. Accordingly, if we want to obtain experimental results having an accuracy of 10 per cent in the transonic region, we must measure the Mach number in the warm air of a shock tube at least with the accuracy of $\Delta M=0.01$ or 5 counts by using a counter of 1 Mc/s pulses. (see Fig. 1(a)) Consequently the author tried to make such a counter and other electronic apparatuses for the measurement that could resolve the time of 1 μ sec. But these apparatuses did not show

Fig. 1. (a)

the required accuracy, so that the author tried various improvements in them. Finally he obtained the apparatuses which could be considered to have an accuracy of at least 5 counts. Usually, for the measurement with a shock tube, a counter with the resolution time of less than 4 μ sec is used. As seen from the facts that Geiger's counter⁵⁾ of resolution time of 1 μ sec was not entirely satisfactory, and that Tamaki⁶⁾ and Kawamura⁷⁾ are using the counters with the resolution time of larger than 2 μ sec, it seems that some problems are still left unsolved for the further investigations. Accordingly, in this paper, the author will report his counting system of resolution time of 1 μ sec. The experiments on the development of detached shock waves in the

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*** These are calculated by the following formula¹⁾

$$s/t = 1.558 (M^2 - 1)^{-\frac{3}{2}}$$

Fig. 1. (b)

transonic region were performed with them, and some results were obtained. These results will

Fig. 2. Shock tube, Schlieren System, Instruments of Measurement and System of Power Supply.

Fig. 3. Electronic Binary Counter.

be also stated here.

2. Shock Tube and Measuring Apparatuses

In Fig. 2 the shock tube used and block diagrams of the apparatuses are shown. The cross section of the tube is 59 mm × 150 mm, and its lower pressure chamber can be made vacuous down to the pressure of 4 mm Hg with a 1/2 IP vacuum pump. p_2 is one atmospheric pressure. The duration of the warm air is about 900 μ sec for $M=1.15$. Only the counter and the negative pulse generator of the measuring apparatuses are shown in Figs. 3 and 4. The other circuits were already reported.^{1),2)}

Fig. 4. Negative Pulse Generator.

3. Discussion on the Measuring Apparatuses

As the author stated in the introduction, he must obtain the exact count at least with an accuracy of 5 counts of 1 Mc/s pulses for the

present experiments. But in the earlier stage of his improvement, the counting system did not show a satisfactory performance. After his precise inspection, he found that many improper components for the circuits caused such errors in count as amounted to 30 counts. In distinguishing a correct count from an erroneous one, he had not an absolute standard of the time interval during which the counter counts the number of 1 Mc/s pulses. Therefore the author considered that the counter, which satisfied the following conditions as sufficiently as possible, should be a good counter.

(a) The required good counter must resolve 1 Mc/s pulses correctly, when the pulses are transmitted to it continuously.

(b) If a delay circuit generates a correctly and steadfastly

delayed pulse, the counting system must always show the same count. This count is the one which is counted during the definite interval of time between the start pulse and the delayed stop pulse.

(c) The experimental results measured with the counter must agree with ones obtained by the methods which are usually used in high speed aerodynamics.

(d) A good counter must show stable counts for a long period of time.

The condition (a) was always satisfied in the present apparatuses. This was made sure with a cathode-ray oscillograph and a low frequency oscillator. By checking the other conditions in the same time, however, the author found that some of them were not always satisfied. If there are no self-oscillating parts in the counter system, the cause of this error seems to be due to the fact that the counting system counts less pulses than the true ones. Therefore the errors in count will become smaller by selecting suitable components for the circuits, so that the counts approach to a definite correct ones. Therefore the following improvements were made.

(1) The power supplies of the counting system are shown in Fig. 2. These stabilized power supplies are connected to the measuring units by the thick lines. The important power supplies are connected to the A.C. power supply (100 v.) stabilized by means of vacuum-tubes.

(2) The voltage of +B has serious effect on the count. We, after many trials, found the suitable voltages for each units (see Figs. 3 and 4).

(3) The values of resistors which connect the cathodes of 6J6s to the ground are important to the counter. By varying the resistances, the variation in count attains to 5 counts at its maximum. Because this variation is a continuous one, the author cannot determine which is the accurate one among them.

(4) The voltage dividing resistors, which are connected to the anode of the output sides of each tubes of the counter, are divided into the ratio of about 2:1 for the first two stages and

3:1 for the rest of the stages. Too low ratio will produce errors in count which may amount to 30 counts.

(5) The grid resistor of the second tube 6C4 of the negative pulse generator (see Fig. 4) is carefully determined. By changing this, the count changes within the limit of 30 counts.

(6) The vacuum-tubes which are used in the negative pulse generator, the gate tube, which is used in the gate unit, and the tubes for the first three stages of the counter are selected carefully from several new vacuum-tubes.

(7) The photomultipliers (see Fig. 2) must be set in their most sensitive position, which will be known by the colour of the Neon-tubes. These are used to stabilize the power supply to the photomultipliers.

The improper components, which were not mentioned above, are changed to the proper ones.

Carrying out checks on the counting system performance, the author found that the present circuits (see Figs. 2, 3, and 4) almost satisfied all the conditions stated above. Accordingly he considers that these counting apparatuses have an accuracy of at least 5 counts of 1 Mc/s pulses.

To obtain a better counting system than the present one, the improvements in the negative pulse generator and the gate unit will be important.

4. Experimental Results

(i) **Experiment with a wedge section having its apex angle of 5°** The model is made of mild steel and has the thickness of 6 mm. The experiment was performed in the warm air. This experiment was made to know how closely the Mach number M_{ap} read from the shock angle of the attached oblique shocks agreed with the Mach number M which calculated from the count of the counter. We see in Table 1 that the agreement is fairly well. Considering that³⁾,

Table 1

M_{ap}	1.23 ₂	1.22	1.19 ₅	1.21 ₀	1.21 ₅	1.20 ₀
M	1.22 ₀	1.23 ₂	1.23 ₃	1.21 ₄	1.22 ₅	1.21 ₃
D μ sec	89	197	298	488	182	170

(D is illustrated in (iii))

as Geiger reported, M_{ap} contains considerable errors due to the bluntness of the leading edges of bodies and the boundary layer over the wedges⁹⁾ in the transonic region, the author cannot say that the condition (c) fully satisfied. But this agreement is an evidence for (c).

(ii) Comparison of pressure ratio p_2/p_0 and shock speed U/a_0^* Fig. 5 shows the results of the present experiment, and those of Kawamura⁷⁾ and Lundquist⁹⁾.

The three results agree fairly well. This is also an evidence of the condition (c).

Fig. 5. Comparison of $U/a_0 \sim P_2/P_0$

(iii) Experiments of detached shock waves

It is the object of the following experiments to obtain a full information about the development of the forms of shock waves ahead of obstacles in the transonic region. In this region, however, a shock tube chokes as the flow around the obstacles becomes stable, so that he cannot obtain the process of development of detached shock waves up to their final stage. But as the size of models becomes smaller, the choking state will come at comparatively final stage of the development. So that he will be able to obtain almost the entire process of the development with a shock tube. Using smaller models, however, the precise flow field at the beginning of the development becomes more difficult to be seen, so that the author uses various size of models to see all the stages of development with the same accuracy. Now the author will define a time D . This is the time duration from the instance when the shock front of a shock tube reaches just ahead of the model, to the instance at which the electric

quantity of 8,000 V is discharged to take photographs of flow fields by Shlieren method. It will be reasonable to consider that the flow field at the time D around the body twice as large as the other will be similar to the flow field at the time $D/2$ around the small size. Therefore, if we use a nondimensional abscissa D/T_0 and a nondimensional coordinate s/t , the results obtained by different size of the similar models will be represented by a single curve, where T_0 is give by

$T_0 = t/U$, t : thickness of models.

U : velocity of shock front.

(The present experiments were performed at the room temperature of about 9° C.).

and

s : the distance of the normal portions of detached shock waves measured the from shoulder of wedge sections.

Figs. 6, 7, 8 and 9 show the results of experiments analyzed by this method. The thickness of models and the mean Mach number in the warm air in which the experiment were performed are shown in the figures.

The curves of s/t for each experiment follow a common envelope up to some values of D/T_0 , and then they part from this curve. They, afterwards, distorted to be finally destroyed in their forms before the attainment of the contact surface to the test section. The departure of each curve from the envelope may be due to the effect of the wall of the shock tube, because this phenomena appears in earlier stage of development for larger models. The envelope of each curves, therefore, will correspond to the location of detached shock waves at each stage of development. Even using the model of 0.6 mm the locations of detached shock waves do not reach the final stable states. In addition, if t becomes smaller than 0.6 mm, s/t seems to become larger. Especially this tendency is seen clearly when $M=1.04$. Considering that on the model of $t=0.6$ mm already the effects of the boundary layer and the

* (about symbols, see Fig. 1(b))

Fig. 6. The Development of Detached Shock Waves.

Fig. 7. The Development of Detached Shock Waves.

Fig. 8. The Development of Detached Shock Waves.

Fig. 9. The Development of Detached Shock Waves.

support of the model is potent, the experiment by thinner models will produce erroneous results. Accordingly the final positions of detached shock waves may be correspond to the maximum values of the envelopes of s/t curves of the present experiments. These values of s/t are compared in Fig. 10, where the experiment for the point corresponding to $M=1.08$ is not shown in details in this paper. The values of s/t for 10° and 180° wedges are almost the same each other for the stages of development at which the comparison

Fig. 10. Comparison of the Ultimate Positions of Detached Shock Waves

is made. Truitt's theoretical value¹⁰⁾ and Griffith's experimental one⁴⁾ are also plotted in it. Considering the accuracy of the present experiments the agreement is fairly well. In Fig. 11 the envelopes of s/t curves are compared. We find that, after some duration of time of development, the positions of normal parts of detached shock waves for 10° and 180° wedges coincide with each other.

Even considering only the results of experiments stated above, it will be reasonable to think that the counting system has an accuracy of 5 counts of 1 Mc/s pulses or 0.01 of Mach number.

5. Conclusions

(1) The counter and its additional apparatuses which have an accuracy of at least 5 counts are made.

(2) The development of detached shock waves ahead of 10° and 180° wedge sections for $M=1.043 \pm 0.01$ and $M=1.143 \pm 0.01$, respectively, are obtained almost up to their final stages of development.

Fig. 11. Comparison of Detached Shock Waves of 10° and 180° Wedges.

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書

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高速流体力学は戦中, 戦後急速に発展し, すでに完成された特有の体系をもつに至っている。したがって海外では現在この方面の成書はちょっと思い浮ぶものだけでも十指に余るほど出揃っている。何といってもこれからの航空の中心課題の一つであるし, 日本でもそろそろまとまった本がほしいと思っていた矢先, 今回河村氏の標記の著書が出版された。同氏は人も知る空力の第一線研究者, また優れた総合報告の著者でもあるので, この本悪かろうはずがない。ただ惜しむらくは講座特殊編の一冊ということで紙数が題目に対してやや窮屈であったことである。

したがって内容が完全流体の定常的な亜音速, 超音

評

速, 遷音速の流れの取扱いに限られたのはやむを得ない。それでもこの分野, とくに超音速流の理論に今日までの高速流体力学の最も大きい成果が含まれており, 本書の重点もまたここに置かれているのは賛成である。全般に基礎的な概念および方法について, かみくだいた説明が親しみやすく述べられて居り, とくに, うっかり見逃してしまう要点, 誤解しやすい個所について所々貴重な注意が与えてあるのも親切で気持がよい。三次元翼理論と遷音速流のくだりはやや馳足気味なので初めての人には多少息が切れるかもしれない。しかしとにかくこれで日本にも標準的なテキストが一つ生れたのはうしろいことである。

本書は応用面に対する配慮も充分なされているので, 実際家にも満足のか参考書となるであろう。

(玉田 琥)