

# 流体控制技术论文集

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### 流体控制技术论文集

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## 前 言

一九七九年全国流控技术学术讨论会是在几次区域性学术讨论会的基础上更加广泛、更具代表性的一次会议。会议共收到论文九十七篇。它反映了我国近几年在这个领域内的研究和应用成果。在会上宣读了其中的四十四篇。

根据会议的建议，将在会上宣读的理论性较强或在应用上有特色的四十四篇论文汇集成本论文集。目的是为了在更广泛的范围内交流经验，以促进今后的研究工作，使流控技术更好地为我国的四个现代化服务。

本论文集分成传感器、元件、功率射流以及线路与装置等四个部分。由于联系面的局限性，有一些好的研究和应用成果未能收集进来。另外由于水平的限制，未免有不当之处，请读者批评指正。

**中国自动化学会自动检测与控制元件专业委员会流控技术学组**

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## ABSTRACT

### Flow Field Analysis and Experimental Study of Vortex Rate Sensor

Kang Zhenghuang, Qi Zhijing, Jiang Songbang

Flow field analysis was given for the Vortex rate sensor, especially with respect to the part of free swirling jet flow field. Location of the apparent origin of the swirling jet was determined; Distributions of the initial region, developing region and established region respectively were studied; Velocity profiles at transverse sections were obtained; "Self-similarity" was affirmed in connection with certain conditions; and the law of decay of axial velocity longitudinally was established. Results of experimental study in Ren-Qiu oil field of North China were given, and the vortex rate sensor introduced was proved to be a feasible device for such applications.

### Design and Investigation of A Fluidic Normal Shock

Position Sensor

Xu Zhenguo

Design, test and investigation of a fluidic normal shock position sensor for Mach №2.6 at mixed-compression supersonic inlet have been discussed. The sensor includes both comparator unit of six OR-NOR elements and memory - power-amplification unit of five bistable elements to detect shock position by sensing the most rearward minimum in static

wall pressure profile. Static and dynamic responses of the sensor were tested repeatedly on the bench. Static response was very satisfactory. The dynamic response couldn't be satisfactory, which was due to the impedance unmatching between the signal device and the comparator unit's elements. In addition, design approaches and characteristic curves of elements are included as well as suggestions for improving the sensor's adaptability. At last, it has been analyzed whether there exist question of "competition-adventure" for sensor circuitry.

### A Fluidic Position Sensor

#### Using Jet Reflection Principle

Yang Huorong, Xu Panliang

Some transfer characteristics of the sensor are tested and analysed qualitatively in this paper. Emphasis is placed on parameter selection, air supply and load which have major effect on The transfer characteristics. Finally, its application examples are illustrated.

### Investigation of The Fluidic Pressure Ratio Transducer

Meng Qingming

The fluidic pressure ratio transducer is a main component of surge-proof unit in the turbine jet-6 engine. The transducer's working principle is introduced and effect of the structural parameters on characters is given in detail in this paper. The results of the bench



test and flight test shown that the operation of the transducer is stable and reliable even under adverse situations therefore fully represents the advantages of the fluidic technique.

### **The Displacement Detection Method Using Dack Pressure Sensor and Proportional Fluidic Elements.**

Jin Zhexue, Pang weitai

This paper gives the experimental results of two types of displacement detection devices used for Strip steel depth measurement. Both devices use the back pressure sensor to convert the displacement signal into Pressure output. The amplifiers use Schmitt trigger, which is used as a pressure switch and its measurement error is 0.002 mm for the displacement detection, and Supplementary devices for monitoring and recording. This device uses a Proportional fluidic element, which is connected to a diaphragm pressure gauge to amplify the fluidic element output. This device can display linear numerical values of displacements.

In the strip steel depth measurement contact type mechanical rolling wheel, which transforms depth to displacements, is used. These devices can be applied to, for example, body position or size detection and closed loop automatic control.

### **Fluid Temperature Sensor**

Jiang Guobin

We have succeeded in studying and making the fluid temperature sensor to measure the temperature in adverse circumstances having corrosion medium, vibration, electromagnetism field disturbance and radiation. The range of measured temperature is from general temperature to 1573K. Average Sensiti-

vity of the sensor is 20—30 Pa/k. When temperature, density and viscosity of the measured medium of the sensor change, the rate of flow also have some corresponding changes. The change of the pressure reflects the change of the temperature of the measured medium. The fluid temperature sensor gives an output signal of direct flow pressure and directly shows the value of the temperature and may match the combination of pneumatic unit. The fluid temperature sensor has been used in automatic regulating system of the temperature of the cooling tower of conbon black production by means of fluidics. This paper gives an initial analysis in theory and proves the conformity of theory and practice.

### **A Noncontact Fluidic Level Signaler**

Yang Fuyu, Guo Haochun

It is not suitable or applicable to use conventional level meter for measuring such liquid which may condense, or move in high speed, or produce a lot of foam, or be in high temperature condition. So developing a new noncontact type level meter is of great significance. This paper describes a noncontact fluidic signaler which were successfully tested in a paint factory, major parts of this signaler include vortex reflect position sensor, adjustable resistor, fluidic proportional amplifier and sensitive pneumatic-electric switch. The emphasis is placed on three special problems: (1) supply pressure selection; (2) blocking protection by purge air; (3) the influence of supply variation. Some test results are also given in this paper.

### **Theoretical and Experimental Investigations of Fluidic Oscillator Flowmeter**

Wu Shi gui, Su Hua nan, Wang Li Juan,

Li Changqi

The authors put forward theoretically a mathematical model for the mechanism of oscillations in Fluidic Oscillator Flowmeter, and developed a new method to analyze the mechanism of wall-jet switches. Theoretical analysis has shown that strouhal number is a constant, if Reynolds number is larger. And a fine linear relation may thus be kept between the flow rate and the frequency of oscillations, as has been proved by the experiments.

**Wall Attachment Bistable Fluid  
Amplifier With Control Duct  
At Down Main Jet**

Li Huilin

Stability is most important for bistable amplifiers. The stability of the wall attachment bistable fluid amplifier evidently increases when its control duct moves down the main jet to a certain value. Model EYS-511 amplifier, a wall attachment bistable fluid amplifier with high stability and good performance, has been designed on this principle. The design method of this type of amplifier and its characteristics are presented. Its applications are also described.

**Ordinal AND**

Guo Dacheng

If signal A is applied earlier than B, the output is 1 when both A and B are 1. This logic is defined as Ordinal AND. The pneumatic Ordinal AND device is a high-pressure poppet sequence element. Its structure is very simple, but it has complex effect in logic. Using of the device can greatly simplify the design on the pneumatic control circuit. This text introduces the structure and property parameter of the new device, and explains its many uses.

**An Investigation and Design**

**Method of a Fluidic Gas-to-Liquid  
Interface Amplifier With Non-  
Linear Characteristic Set Arbitrarily**

Lin HongZuo, LuoZhi Chang,  
Yan XiaoChen

This paper offers a principle of a non-linear fluidic gas-to-liquid amplifier which has a special structure of splitter, i. e., the profile of splitter utilizes a three-dimensional curve. Its  $\bar{G}-\bar{P}$  characteristic could be arbitrarily scheduled to fit in with a desired function.

**Fluidically Controlled Vitreous  
-Infusion-Suction-Cutter (FC-VISC)**

Chen yinqing, Yu Lihe, Hau Zheng qing,  
Li peide

This paper describes in detail the principle of fluidic controlled reciprocating type vitreous-infusion-suction-cutter, performance and construction of pneumatic and fluidic elements.

This device has been certificated technically. It has following advantages, simple in construction, low-cost, with a light and small handle, strong cutting force, excellent response characteristics of the suction part, larger infusion adjusting range, convenient operation. It can be sterilized by means of autoclave, boiling or immersion in disinfectant fluid etc.

This device can be used in The treatment of various vitreous body diseases incurable in the past. Since Feb. 1978, It has been successfully used in more than 200 surgical cases and obtained satisfactory results.

**Theory on The Fluidic Shock-Drill**

Wu Shiqui

Fluidic shock-drill is a new type of geologic drilling tool. This paper invest-

igates their principles and characteristics. The present author gives an analytical model on their dynamical behaviour based on the theory of Common Mechanics and Fluid Dynamics. Good agreement is obtained between theoretical and experimental results.

#### **A Preliminary Study of The Matching Between A Fluidic Element and Its Load in The Impacter**

Tian Yonquan Peng Jianshu

This paper deals with the match between a fluidic element and the piston mechanism as its load in the impacter. The authors derived the motion equation of the piston mechanism so as to build up the approximate relations among the parameters such as velocity, travel and time (thereby the shocking work and frequency can be deduced), the output characteristic of the fluidic element and the constructional parameters of the piston mechanism. Based on the experimental data, the effect of the switch characteristic of the fluidic element and the sealing situation of the piston mechanism on working state of the impacter are also discussed. The matching condition of the fluidic element and its load for vibration is suggested.

#### **Determination of The Supply Flow and The Size of The Power Nozzle of The Power Water Fluidic Element With A Piston as Its Load**

Tian Yongquan Peng Jianshu

In this paper, the output performance of the power water fluidic element with a piston as its load under the operating condition with all return flow is investigated experimentally. On the basis of the experiment, a design method to

determine the supply flow for the fluidic element and the size of its power nozzle on the principle of utilizing the energy efficiently is presented.

#### **An Investigation of The Transmission Characteristics for Fluidic Digital System By Using Travelling Wave Theory** Luo ZhiChang

In order to derive the transmission Characteristics of fluidic digital system, the travelling wave transmission models and their parameters of fluidic pipeline junction are presented in this paper. Using these model parameters, the author calculates the transmission characteristics of two different typical fluidic circuits. A good agreement is obtained between theoretical and experimental results.

#### **Planarization of Fluidic Pulse Width Modulator** Peng Minqi

This paper discusses the problem of planarizing the fluidic PWM by increasing the input impedance of fluidic bistable elements. The discussion emphasizes the topic of how to establish a mathematical model which closely approximates the distributed system dynamics of the feedback network working in medium and low frequency range. The problem of how to simplify high order system is also paid due regards because of its utmost importance in solving the dynamic equations in question. Actual computation indicates the combined use of distributed — lumped parameter approach, method of decoupling and model simplification techniques could solve highly complex problem into an easily computable routine of algebraic nature, and could be handled by a hand-held calculator or a programmable calculator of

simple type without having to rely on expansive large scale machine computation. Sample calculations demonstrated the above mentioned methods possess both simplicity as well as precision, it also bring forth the conclusion, that the lags and pure delay (dead time) of the feedback circuit and first stage amplifier are the chief obstacles in raising up the working frequency of the PWM.

The conclusion also points out that both the dynamic and static properties of feedback network play a decisive role in giving the kind of characteristic to PWM as desired.

#### **Investigation of a Control Circuit of High Sensitive Fluidic Pulse Width Modulated (PWM)**

Gie Sinbao

High sensitive fluidic PWM control circuit is an effective device we now have in operating the analog fluidic signals. The input of the pre-circuit is an analog signal of weak air pressure. The signals are operated, width modulated and been in the form of Square wave signals with considerable power capacities as its output. Based upon extended experiments on the circuits, following propositions are discussed in this paper,

- a) principles of increasing the sensitivity of modulation and maximum rate of modulation of the circuits are noted
- b) In increasing the sensitivity of modulation, the instability of the output wave shapes are followed as a result. Two important factors are observed. One is that the stochastic effects on the width of the output waves become more and more important as sensitivity of modulation increased. The second is that the stochastic high frequency pulses

occurring in output Square waves formed by the noise of proportional amplifier appear more and more significant in the same circumstances. The former is referred as "pulse width variation" and the latter is referred as "noise of modulation". Both terms are explained in the text. Principles related with the instability of the wave shapes are thereby discussed.

c) In order to improve the above mentioned two effects, proper design of the circuits and the constituent elements are given.

Dynamic testing circuits and related data are provided in the paper.

#### **D. C. Controller and Its Reliability** liu JianHou. Fan liangxing.

This paper describes the cascade method between two fluidic jet-interaction proportional amplifiers and gives an analysis of a negative feedback d. c. Controller circuit and its characteristics. The transfer-function and frequency-characteristics of the controller have thus been derived, and the reliability of the controller determined. Through the reliability tests of the cascade circuit of jet-interaction-proportional - amplifiers and controller, Test data regarding the effect of the environments on the reliability of fluidics-controller and the solution method have been obtained.

#### **The Gasoline-Supplying Principle and System Analysis of The Fluidic Controlled Carburettor with Three Parallel Components**

Liang Hongming Liu Guochong

The fluidic controlled carburettor, which came into being with the advent of the application of fluidics to the automobile engine and has been adopted in the gasoline-supplying system of the engine, possesses many unique advan-

tages. This treatise deals with the basic structure. The principle of gasoline-supplying and the system analysis of the fluidic controlled carburetters with three parallel components, thus deducing the equation of balance of flow. Expounded in the treatise is the principle of gasoline saving achieved by virtue of positive pressure injection, secondary foaming and hit atomization caused by multiple oil pencils. It has been proved that the atomization in the fluidic controlled carburetter gets better and it can meet the needs of the engine for oil flow of any characteristic.

The fluidic controlled carburetter with three parallel components (ASH101) has got the technical testimonial and passed the test of twenty thousand kilometres in a moving automobile. It has been proved that not only does the dynamic performance come up to the standard, but its rate of the gasoline saving is up to about 8%, and vapor locking has been prevented. For the purpose of economizing energy resources, it is of great value to introduce the fluidic controlled carburetter at the present time.

#### **The Fluidic Automatic Regulation of Temperature in Cooling Tower in Production of Carbon Black**

**Jiang Guobin**

From the point of view of simplifying regulating system, increasing regulating function and convenient use, we study and test the fluidic modulator of pulse width to centre around the fluidic digital component. Its basic principle is to compare the output signals of transducer with the values of command and magnify by means of the first grade plane impact modulator. The magnified deviation signals are added to a pair of control paths in the oscillator

directly. The values of deviation can change output pulse's frequency and width of oscillator. The transducer member is a fluid temperature transducer made by us, its construction is simple, and its quantities are better. This regulating system has been used to the production successfully.

#### **Fluidic Analog Self-Alignment System For Steel Belt Sheet Production in Acid Washing Tower** **Tong Shiaooshin**

This paper presents a analog type fluidic position regulation system used in a steel sheet production in an acid washing tower. The working principle is discussed and the long distance fluidic position analog sensor, proportion amplifier and pneumatic-hydraulic serve valve are emphasized. The regulating characteristics of system is explained through the theoretical derivation of transfer function of steel sheet belt position to piston position of hydraulic cylinder and some static and dynamic tests.

#### **A Fluidic Automatic Correct System for Narrow Slot Welding Process**

**Yang Huorong**

This paper deals with the test and analysis of fluidic jet reflection position sensor and the fluidic automatic correct system using that sensor. Special stress is placed on analysing system stability and accuracy.

#### **Design and Study on Digital Fluidic Controller of Flow Quantity**

**Cheng Guojun**

**Li Yueqin Liang Jingchang**

The operating principles of digital fluidic controller of flow quantity and its practical application in automatic control of measuring fuel oil are given.

Also the operating principles and their construction features of fluidic ring numerator, pneumatic translator, pneumatic multi-input OR gate element, pneumatic oscillator, pneumatic indicator are described. And improvements of their reliability and control accuracy are discussed.

#### A Fluidic Tape Input Device

Li Jianfan Chen Dengwu

Zhang Huanchuan

The fluidic tape input device is an important device of digital fluidic control system. This article developed a step-by-step type intermittent input fluidic tape input device, that makes use of the standard five-hole punched tape and each sequence has the twenty-four order.

On the basis of analysing and comparing with the present available informations, as a result of a series of test to the interrupting type tape hole sensor, a more ideal size parameter of tape hole sensor was determined. It is as follows: the transmitter hole diameter  $\phi 0.5\text{mm}$ ; the receiver hole diameter  $\phi 0.85\text{mm}$ , the space between two face  $\delta = 0.25 \pm 0.05\text{mm}$ . As a result of practical measure of this sensor, in load with one fluidic element conditions, the pressure recovery more than 20%, the relative disturbance less than 1% are obtained. On the basis of this test we have designed a reader and developed the control circuit driving and positioning the tape.

#### The Fluidic Control Equipment of Moulding Automaticline With Casting

Peng Shouzhan Tan Haitao Tang Shimei

This paper present the design technique production line for the manufa

cturing of casting model. Ample proof obtained from practical operation on the production line shows that the adoption of fluidic automatic control system to fit the need of vibrating type of pneumatic casting model production process, is not only cost effective but also a highly rational and favourable among other techniques.

#### The Application of Liquid-Fluidic Technique and the Prospect of Its Development

Wu Zhunxian

The thesis Primarily describes the current circumstances of the application of liquid fluidic technique and problems unsettled therein. It also explains various liquid fluidic elements and the application system composed of such elements. Further, it demonstrates the short cut of improving the application of the technique, and gives an account of the technique's prospect in its application.

The major contents of this thesis contain four section of which:

Section 1: The present situation in the application and evaluation of liquid fluidic technique.

Section 2: The elements and application system. Also an introduction of the application of elements using water as a medium.

Section 3: Improving ways of the application of the technique.

Section 4: Prospect of liquid fluidic development.

#### The Fluidic Application in the N. C. System Chen Keyou

By discussion to a 2-coordinate continuous trail fluidic control system, this article is for the ranking of the foreground of the fluidic application in the

N. C. systems.

The article described the working principles and the procedures of the system, and discussed specifically several main devices and analysed the stabilities and safetilities, and also discussed the way of improving the safetilities and their test methods.

### The Application of Hydrocontrol Technology to the Remote Control of Marine Main Engines

Chang Chukun, Bao Chingguo

In this paper two parts is narrated, 1) the fluidic logical system; 2) the pneumatic speed governor system.

The construction of the two systems are very simple, and, therefore, may be installed anywhere in an engine room, and thus convenient to maintain.

In the first part, we decided the working procedure of "ahead", "stop", "astern" and "start" of the main engine, and based upon which its scheme of control system (block diagram) is drawn.

Then, according to the control procedure of conventional main engine, we have obtained a very simple and useful logical system through "Karnaugh" diagram. However, 8350 type engine is different from conventional main engines,

some elements have, therefore, to be added to the system.

In order to reduce energy consumption, we have introduced solenoid valve to shut-off air source when necessary.

The second part deals with the construction of the pneumatic speed governor. It is made up of operational signal integrating amplifier, driving elements and vortex sensor. We have obtained a transfer function of the linear simulation system.

The speed governor can not only adjust speeds, but also control speed shifts, such as from "ahead 1" to "ahead 2", "ahead 3" etc., with an adjustment deviation less than  $\pm 10$  m. p. The vortex sensor is approximately a kind of linear characteristic element. Through experiments, we have chosen the straightline section as pressure signal and being applied to the speed governing of the engine.

The working media is compressive air, with a pressure up to  $13.72 \times 10^4$  Pa.

this system and the manual operational system are separately installed, the automatic control is, therefore, a multiple system.

# 涡流转速传感器的流场分析及实验研究

康振黄 戚志晶 姜松邦

## 一、意义及背景

涡流转速传感器是把流体和转动物体的运动耦合起来,利用流体的压力与转速之间特定的对应关系,来感测旋动物体转速的一种流体传感器。由于这种传感器中所动作的是流体而不是机械部分,因而不存在磨损和复杂的结构问题。在很多调速系统中,由于执行部分是用流体驱动的,采用涡流转速传感器可使系统的工作介质单一化,减少由于工质转换而带来的复杂性。此外,由于涡流转速传感器可在恶劣的环境和特殊的场合(如严重的油雾污染,浓泥浆,强腐蚀、高温、低温等等)下工作,因而在许多工程应用中作为检测仪器,可以得到稳定的数据结果,以达到电器和机械传感装置所不能达到的目的。

涡流转速传感器的基本结构如图1所示。输入气流由输入管进入输入环,然后再到槽环。随着转子的转动,使得在涡室内的流体与转子的转速有机地耦合起来,经过发射管,形成自由旋动射流,接收管所接收的信号即为这一旋动射流的压力信号。这种传感器的工作原理和设计方法详见“涡流转速传感器的流场分析和设计研究”<sup>[1]</sup>,它的主要流场及作用可归纳为如下三个部分:

(1)流体在转子与壳体之间环区内的旋转运动,起耦合作用。

(2)流体在涡室和喷射管内的自由涡流动,起放大作用。

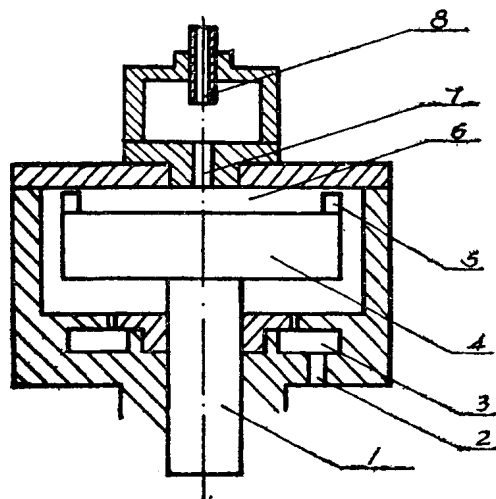


图1 涡流转速传感器结构

1转轴 2输入管 3输入环区 4转子 5槽环  
6涡室 7喷射管 8接收管

(3)流体在排空区内的自由旋动射流流动,起检测作用。

本文着重对第二部分的流场和在实验室及现场的实验研究作一较为详细的阐述。

关于自由旋动射流的研究,国内外均有不少报道,就我们所知,主要有如下的一些情况:

较早的有W.G.Rose提出的实验研究<sup>[1]</sup>。他所用的方法是用鼓风机送气至一个转动着的长管内,在管的排气端形成旋动射流。在该实验研究中,一方面,所形成的旋动度很弱;另一方面,在实验中只限于形成一个旋动强度值。因而所得的结果只表明有旋动和无旋动的流场情形,而没有关于不同旋动程度下的比较结果。



R.W.Gore和W.E.Ronz用旋转的穿孔盘做过实验<sup>[3]</sup>,对轴向流动加以旋动。实际上,其结果应当看作是尾涡和旋动射流的组合,而不单是旋动射流的流场。

与上项实验发表的同年,N.A.Chigier和J.M.Beer发表了经过环形和扩张形喷嘴流出的旋动射流的速度和静压分布的研究<sup>[4]</sup>。利用切向注入方式,使管道内的轴向流动得到不同程度的旋动程度,形成有旋动的轴对称流。

其后,N.M.Kerr和D.Erazer用斜槽式通道形成旋动射流,进行过实验研究<sup>[5]</sup>。后来,N.A.Chigier和A.Chervinsky续发表有关的理论研究和实验研究结果<sup>[6]</sup>。M.L.Mathur和N.R.L.Maccallum采用叶片式旋动发生器进行过旋动射流的研究<sup>[7]</sup>。

在测量方面,光阔豊一测过多孔环形成的旋动射流的轴向压力分布<sup>[8]</sup>。J.W.Berr和N.A.Chigier在燃烧空气动力学<sup>[9]</sup>一书中有过流场测试方面的研究概述。

直到近些年来,有关研究仍不断有发表。例如苏联1976年发表了关于一股轴射流当其内层有初始旋动或外层有初始旋动时的流场效应研究<sup>[10]</sup>。日本1978年发表了有关旋动和直动射流的比较研究文章<sup>[11]</sup>。

所有以上这些研究,都有如下的一些特点:

(1)旋动射流的发生方式主要是利用“切向注入式”、“斜叶导流式”以及“多孔环式”。

(2)研究的范围,一般多在旋动度较大的情况,以针对燃烧器应用为主。

(3)研究目的着重阐明旋动射流流场本身的居多,涉及与有关构件形成整体的总的特性分析方面的研究较少。

我们结合涡流转速传感器的研制应用,对旋动射流进行了一些区别于上述特点的研究。

## 二、流场特性分析

### 〈一〉特点:

(1)在旋动射流的发生方式上,采用转子在壳体内旋动时产生的粘性耦合作用和涡流室内的角速度放大作用,使射流经喷管流出时成为有一定旋动强度的旋动射流。这种作用方式既区别于“切向注入式”、“斜叶导流式”,也区别于“多孔环式”,我们称之为“内转式”。之所以采用这种作用方式,一方面是为了适应研制转速传感器的需要,另一方面也是为了探讨这种旋动射流在流场结构和特点上与别的发生器所形成的旋动有无不同。

(2)使旋动强度在较大范围内变化,由静止到弱旋、中旋、强旋,以便研究在较大范围内旋动强度变化时流场特性的影响。我们所测试的旋动数为: $S=0.09, 0.21, 0.30, 0.47, 0.62$ 。其 $S$ 定义如下:

$$S = \frac{G_s}{G_z r_0} = \frac{\text{射流沿轴向的角动量率}}{\text{射流沿轴向的动量率} \times \text{喷口半径}}$$

(3)把旋动射流流场的研究和利用这种流动现象所制成的转速传感器的整体特性研究结合起来,通过研究旋动射流的流场规律,建立这种传感的性能预测方程,促进这种传感器的设计和研制。

此外,在这次研究中,我们主要就旋动射流的轴向速度进行了研讨。为了便于进行普遍广泛的测试,所用测试方法为通过测压法反映流速分布,即装置针对旋动射流的接收管,测取接收管为闭塞状态时的表压力值,然后利用:

$$P_r = \frac{1}{2} \rho W^2 \quad (1)$$

换算成流速。

其中: $P_r$ ——接收管压力,

$\rho$ ——流体密度,

$W$ ——轴向速度。

### 〈二〉实验装置 分两部分:

(1)旋动发生器,如图1,当转子转动时,