THE SURFACE ROUGHNESS MEASUREMENT OF METALS USING MICROWAVE

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ABSTRACT

A new principle of surface roughness measurement of metals using microwave is developed. The relations between surface roughness and reflected microwave power are found for the first time. A single chip microcomputer is used for processing and displaying the results. This method features non-contact inspection and real time operation as well as high accuracy and ease of application.

INTRODUCTION

The surface roughness is one of important quality specifications. It is characterized by contour arithmetic mean deviation Ra, which is defined as follows in Fig.1,

$$Ra=1/n(|Y1|+|Y2|+......+|Yn|)$$

The contour arithmetic mean deviation Ra is usually measured with interferometer or electrical contourgraph. The disadvantages of these methods lie in either non-real time operation or contact inspection.

This paper describes a new principle of the surface roughness measurement, which is based on scattering property of rough surface under microwave radiations. The apparatus includes a microstrip disk radiator and cubical dipole antenna, which is used for receiving microwave power reflected from metal surface and converting to DC voltage. The relations between the surface roughness and reflected microwave power is obtained by means of a series of standard sample tests.The range of roughness measurement Ra is 0.01 μm-2.00 μm. Less than 5% errors has been achieved.

The apparatus is of several advantages over conventional methods: high accuracy and rapidity as well as ease of application.

PRINCIPLE OF MEASUREMENT

Let's consider vertical incidence of uniform plane wave upon an interface between air and metal plate. If the metal is a ideal conductor with a mirror face, the vertical incident wave will be full reflected, Otherwise because of the rough face, a portion of the incident signal will be scattered and deviated from the vertical direction. The rougher metal surface, the less is reflected microwave power in vertical direction. Thefore the surface roughness of metals can be evaluated by the amount of vertically reflected microwave power.

the block diagram for measurement apparatus is shown in Fig.2 . The signal of microwave generator is feed to microstrip disk antenna and radiates to rough metal surface. The reflected microwave power is received by a cubical dipole antenna, which make use of the thermocouple effect. Thus induced electromotance on the dipole antenna is changed into DC voltage, which is

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directly proportional to the square of strength of electric field, i.e. reflected microwave power. The DC output is indicated on a microammeter and sent to a single chip microcomputer to process and provide display of roughness measurement results.

In our experiment for a variety of standard samples of steel , their roughness are known in advance, so the criterion curve of surface roughness vs magnitude on microammeter is able to acquired. For unknown surface roughness,as long as the magnitude on microammeter is read and compared with the criterion curve, the surface roughness of tested component can be easy calculated.

PRACTICAL CONSTRUCTION

As shown in Fig.2 ,the test apparatus contains,

(1)Microwave Generator

The generator is a Gunn diode oscillator, which provides desirable microwave power and 9780 MHz frequency. The generated microwave signal is feed to microstrip disk antenna through attenuator and waveguide to coaxial line adopter.

(2)Microstrip radiator(1)

The microstrip radiator is a circular disk microstrip antenna. It is fabricated on Reinforced Teflon substrate. In this antenna, the radius of disk is 5.3mm, which can be calculated as follows,

$$a=k/\left[1+\frac{2h}{\pi\varepsilon_r k}\left\{\ln\left(\frac{\pi k}{2h}\right)+1.7726\right\}\right]^{1/2}$$

$$k=8.794/f_r\sqrt{\varepsilon_r}$$

Where a is the radius of disk in cm,
h is the thickness of substrate in cm,
fr is the operating frequency in GHz.

Fig.3 illustrates the coaxial feed excitation for the circular disk microstrip antenna. The coaxial external conductor and the center of circular disk are attached to the back ground of printed circuit board, while the coaxial internal conductor is connected to a point from center of the disk about 1/3 radius long.

(3)Microwave Sensor(2)

In fact, the microwave sensor is a cubical dipole antenna, which extracts the reflected microwave power from the measured metal plate. It is composed of three dipole antennas, which are perpendicular each other in space and in series connection one by one. Each dipole have two functions:

(a)Since total two arm length of a dipole is about half wavelength, so it is able to receive microwave signal very effectively.

(b)The two arms of a dipole are connected to the two ports of Bismuth-Stibium thin film thermocouple, which is realized in vacuum evaporation technique. By means of thermocouple effect, the received microwave signal on the dipole will be detected into DC output.

Fig.3 illustrates the arrangement of a pair thermocouple,which is orthogonal each other.The third diople is inserted in perpendicular to form a cubical antenna as microwave sensor.

The microwave sensor is fixed on a comical pedestal,which is made from dielectric material with low loss and covered by a spheric foam polystyrene radome to protect the sensor from the damage and infrared rays influence.

(4)Single chip microcomputer minimum system

The DC output voltage is sent to interface of minimum application system through operation amplifier, A/D converter and buffer memory. A single chip microcomputer 8031 and latch 741s373 and a program storage EPROM 2716 make up the minimum application system. The last part is the display unit, which contains a shift register and LED display to show the surface roughness of the metal.

EXPERIMENTAL RESULTS

When using this apparatus, it is essential that the circular disk antenna should be parallel the surface of metal to ensure vertical incidence and adjusted in appropriate distance above the surface of the metal. In addition the angle between two axis of the disk patch antenna and conical pedestal of microwave sensor is needed to select a optimum value (typical value is about 8 degrees).

In our experiment, nine standard steel samples, which have different contour arithmetic mean deviation Ra, are utilized. The measured magnitude of microammter μA(x) for a variety of Ra is listed in Table I below.

Ra(μm)	.01	.016	.032	.063	.125	.25	.50	1.0	2.0
μA(x)	4.05	2.3	1.2	.62	.32	.15	.08	.04	.02

Table I the relation of Ra vs μA(x)

The fitted curve of Ra vs μA(x) is shown in Fig.5. In the practical roughness measurement, if μA(x) is detected, the surface roughness will be determined with the help of the fitted curve.

On basis of above data, a fitted curve equation is derived as follows by least square method,

$$Ra=1/25.7503X$$

Where Ra unit is in μm ,
X unit is in μa .

In the minimum system, a program for processing the fitted curve equation is solidified in the EPROM to make use for display the result. Less than 5% mean errors by the single chip micrcomputer are demonstrated with a series of standard sample tests.

Finally, it should be noted that the principle is also suitable for roughness measurement with spheric and cylindric surface. In fact, the measured results shows they are very similar to that with plane.

REFERENCES

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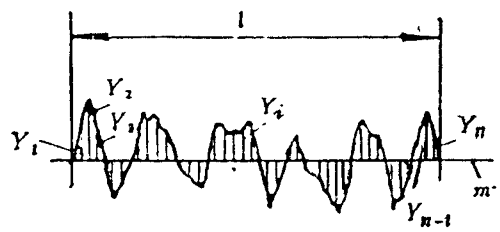

Fig.1 contour arithmetic mean deviation

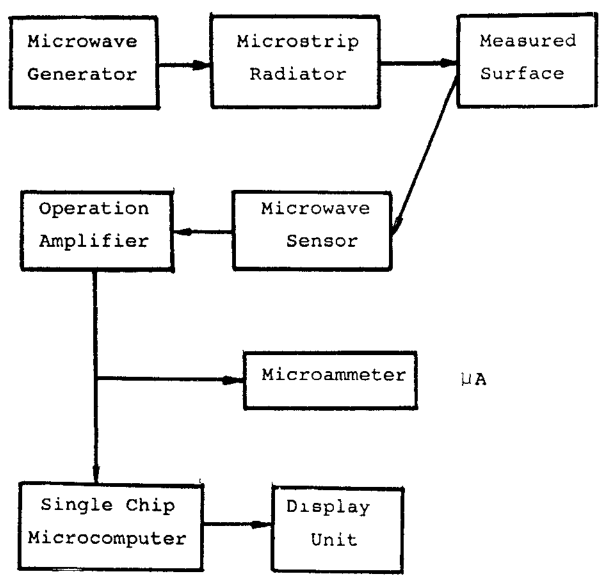

Fig.2 Block diagram of measurement

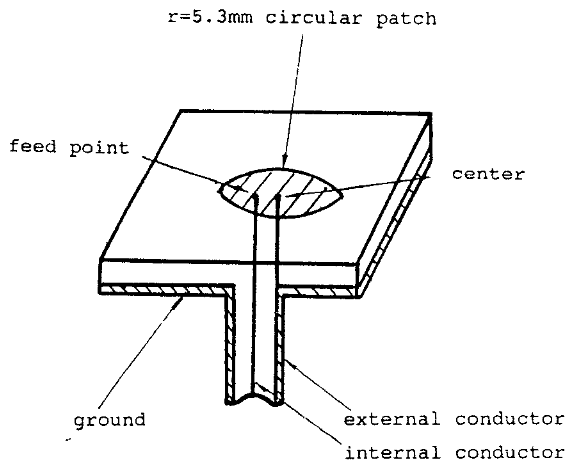

Fig.3 The microstrip radiator and
coaxial feed diagrammatic sketch

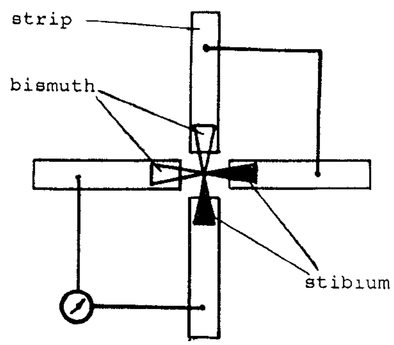

Fig.4 Two orthogonal thermocouple
dipole antennas diagrammatic sketch

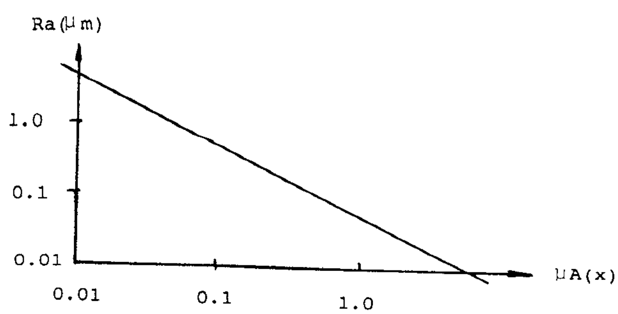

Fig.5 Fitted curve of Ra(μm) vs μA(x)