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A Platform for Properties Investigation of Narrow Gap Electrostatic Discharge

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***Abstract*—A new measurement platform testing electrode moving speed effect on discharge parameters was designed and manufactured following analysis of problems in references and pondering thought. The novel testing platform took advanced of structure of crank link motion gear and mechanotronics. The problem hence was resolved by the new design: that electrode need to move at high speed to the target but must avoid strong collision for protecting instrument from damage—which has perplexed researchers for long time. Theoretical analysis and algorithm on electrode moving speed effect were given based on two basic theorems in fluid mechanics. The platform was employed to verify primarily result from theoretical and algorithm analysis of electrode moving speed effect. Discussion was given, at the same time, on influence of discharge result caused by variation of gas pressure.**

Keywords—electrostatic discharge, moving speed, discharge parameter, discharge gap

I. INTRODUCTION (*HEADING 1*)

In practice application process of international electrotechnical commission standard[1] IEC61000-4-2 there is a possibly problem of discretization of test results (i.e. low reproducibility). Various circumstances factors, as a matter of fact, electrode moving speed to the target, for instance, gas pressure, temperature and humidity, etc. can impact on the result of electrostatic discharge event in the real world. The regulations have been given in the standard IEC61000-4-2 on contact electrostatic discharge events, but one cannot find regulars on non-contact electrostatic discharge. In 1980's of last century B. Daout, H. Ryser, A. Germond, etc[2] proposed that approaching speed between charged object and victim object will have distinctive influence on discharge parameters. David Pommerenke, et.al.[3][4][5] in Missouri University of Science and Technology designed a setup which can measure electrode moving speed to the target. Researchers in Shijiazhuang Ordnance Engineering College[6][7] proposed a setup in which the ESD generator moving along an arc trip and can be roughly equal to straight line motion to the target. Takeshi Ishida, Yukihiro Tozawa and Osamu Fujiwara[8] reported their work on spark Length determining affected by approach speed with a setup charged object can move to the target at two different speeds. Several researchers[9][10][11][12][13][14]discussed the problems on properties variation of discharge gap. There are two problems, however, in setup previous mentioned. At the first, charged object can not move at high speed to the target due to possible strong collision which may damage the instrument. Secondly, all previous mentioned experiment systems are working in open circumstances, so various factors can not be controlled easily. A new platform invented by our team, in this paper, will be described in section II. Then theoretical analysis and brief algorithm on electrode moving speed effect is given in section III. Following that, in Section IV is to discuss influence of gas pressure on discharge parameter and a brief verification with the new platform. At the last, in Section V, a conclusion is provided.

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II. STRUCTURE OF NEW TEST PLATFORM

The new measurement system[15] of electrostatic discharge has its structure shown as in Fig.1. The system includes sealed box in which gas pressure can be measured and controlled, guiderail and its support, crankshaft and connecting rod, electrostatic discharge generator(so called ESD gun) driving by crankshaft and connecting rod, discharge target(current detector), etc. ESD gun could be driven along the guiderail

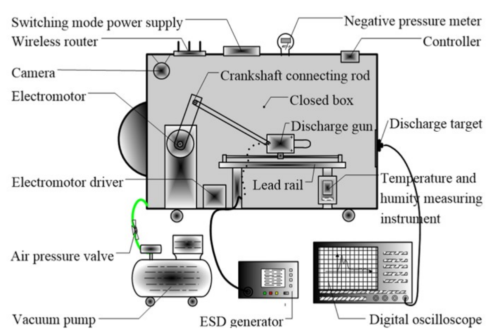

Fig.1 Structure of new test platform of ESD

moving forward or backward. Rotational motion is transferred to straight line motion through crankshaft and connecting rod. ESD gun can be driven along the guide-rail to the target and back. Electrode fixed on the ESD gun could be driven back at the time before contacting the target. In this way, electrode could move at high speed to the target and could avoid to collide strongly with the target ---- provided a completement resolution to the difficulty problem perplexing researchers for tens of year since 1987.

III. THEORETICAL ANALYSIS OF MOVING ELECTRODE SPEED EFFECT

Electrostatic discharge(ESD) will take place as long as the media(gas) between charged object and the target breakdown due to electric field reached and exceeded the threshold value of breakdown[16][17]. Gas in discharge gap is a fluid and hence obey basic laws and theorems in fluid mechanics. Flow conservation law and Bernoulli theorem are two laws in fluid mechanics. Supposing point A and B are two points in the gas flowing tube(see Fig.2). At point A, p_A is gas pressure,

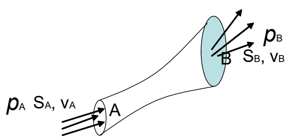

Fig. 2 Flowing tube and corresponding quantise

S_A cross section area, v_A flowing speed, Q_A flow passing through S_A. At point B, p_B is gas pressure, S_B cross section area, v_B flowing speed, Q_B flow passing through S_B. So, we can have the following derivation

$$S_A V_A = S_B V_B = \text{const} \tag{1}$$

$$p + \rho g y + \frac{1}{2}\rho v^2 = const. \tag{2a}$$

$$p_B - p_A = \frac{1}{2}\rho(v_A^2 - v_B^2) + \rho g(h_A - h_B) \tag{2b}$$

Where ρ is density of air, h the height to ground.

In summary, we can obtain formulars as the following

$$p_A = p_B - \frac{1}{2}\rho\left[\left(\frac{S_B}{S_A}\right)^2 - 1\right]v_B^{\ 2} \tag{3}$$

$$\left[\left(\frac{S_B}{S_A}\right)^2 - 1\right] > 0 \tag{4}$$

$$p_A < p_B \tag{5}$$

Supposing V_{rf} to be the speed of electrode moving to the target, gas flow in discharge gap will varied with electrode moving to the target(see Fig.3(*a*) and Fig.(3*b*)). If electrode moving speed to the target, a flowing tube will be formed in and out side the gap. Gas flowing speed v_A and cross area S_A at point A is different from that at point B (v_B, S_B), so if applying two principles of flow conservation law and Bernoulli's theorem in fluid mechanics, we could derive that $P_A < P_B$.

But if the electrode moving at slow speed or zero speed to the target, there will be no flowing tube formed, and hence $P_A = P_B$.

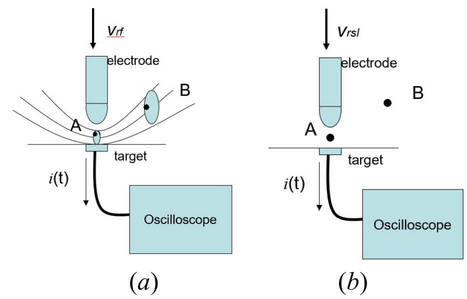

Fig.3(*a*) Fast speed of electrode resulting in $P_A < P_B$
Fig.3(*b*) Slow speed of electrode resulting in $P_A = P_B$

According to Townsend's gas discharge theory[18], discharge current in ESD process is related with the first coefficient of ionization α

$$i = i_0 e^{\alpha d} \tag{6}$$

$$\frac{\alpha}{P} = A\exp\left(\frac{-B}{E/P}\right) \tag{7}$$

Where: i discharge current, α the first ionization coefficient, d gap distance, P gas pressure, E electric field intensity, A and B are two constants related to the type of gas.

IV. ANALYSIS OF MEASUREMENT RESULT

A. Discharge result variation with electrode moving speed

Applying the new measurement system described in section I discharge currents affected by moving speed of electrode to the target and gas pressure variation can be obtained in experiment of electrostatic discharge. Keeping charge voltage at certain value and changing electrode moving speed to the target discharge current will variate accordingly (seen Fig.4). If electrode moving fast (Seen in Fig.4) to the target, the peak value of discharge current will be distinctively larger than that for electrode moving slow to the target

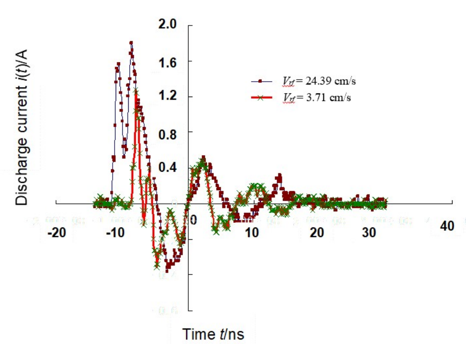

Fig.5 discharge current varied with electrode speed

B. Gas pressure influence on discharge current

Gas pressure is an important factor impacting on discharge result in small-gap electrostatic discharge process. With experiment system described previously in section I, measured discharge current variation with change of air pressure in discharge gap are shown in Fig.5 and Fig.6 as the following.

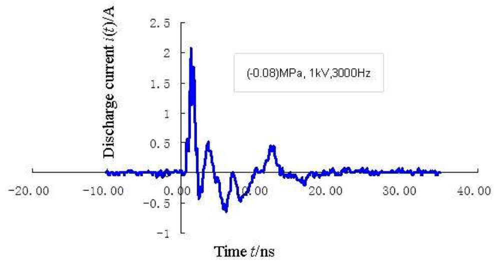

Fig.5 Discharge current with large gas pressure

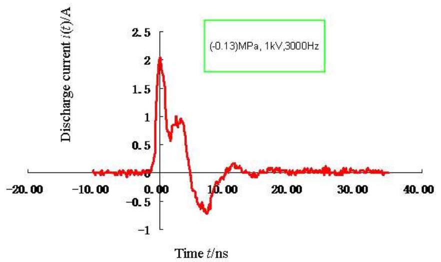

Fig 6 Discharge current with small gas pressure

Measured discharge current for comparatively high gas pressure(means low vacuum degree) is given in Fig.5, in which gas pressure is -0.08MPa(≈0.92atm), charge voltage is 1kV, velocity of electrode moving to the target is 0.087m/s. As in Fig6 gas pressure was reduced lower to -0.13MPa (≈0.87atm, means comparatively high vacuum degree), the charge voltage and electrode moving speed to the target are the same as in Fig.5. The start time point of rise slope in discharge current, seen in Fig.6, is earlier than that in Fig.5, which means high vacuum is contributing to faster rise slope than that in low vacuum. gas.

V. Conclusion

The test system of moving electrode speed effect provide a new path and a basic platform for research on discharge result affected by multi-factors of electrode moving speed, gas pressure, temperature, etc. Principle of flow consistency and Bernoulli theorem in fluid mechanics were employed to analyze variation of discharge current caused by gas pressure difference, which, in turn, resulted from electrode moving speed. Theoretic analysis was verified briefly with the new test platform. The upgraded ESD test platform provides opportunities for research into properties and mechanisms of contactless electrostatic discharge. Research results could lead to proposals for changes to existing standards, or for new standards on contactless electrostatic discharge.

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