Point cloud analysis method for high voltage breakdown and creepage problems in metal-encapsulated Microsystems

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Abstract: In the face of the potential breakdown and creepage risks in metal encapsulated high-voltage isolation Microsystems, a new reliability analysis method combining high-precision modeling and graph theory was established in this paper to provide a strong guarantee for product design and testing. Firstly, the 3D model of the microsystem is transformed into a point cloud model, and a computable numerical model is formed by filtering and surface reconstruction. Then, according to the geometric characteristics and physical relations, the surface creepage problem and breakdown problem are equivalent to the calculation of geodesic path and Euclidean path respectively. The Dijkstra algorithm is optimized according to the layout of microsystem, and the breakdown and creepage paths after packaging are calculated. Finally, the risk level of the product is judged by reference to the experimental standard. The results of the control experiment match with the calculation, and the precision is ideal, which shows the effectiveness of the method for microsystem-related problems.

Key words: microsystem; Point cloud analysis; Dijkstra's algorithm; Breakdown phenomenon; Creepage phenomenon

Introduction

The integration of high voltage isolation chip, controller, configuration circuit and other modules into a microsystem form can significantly reduce the size of the product and improve the adaptability of the scene. However, in the limited space, the product package will introduce bonding wire, shell, cover plate, welding column and other metal structures, whether it will result in new breakdown behavior in the industry there is no method to analyze and determine, but this kind of microsystem devices must be considered in the design of reliability factors. After analyzing the physical composition of many products, it is found that the breakdown problem inside the isolation microsystem can be summarized into two categories: the minimum interval between the two networks before and after the isolation of the substrate surface is less than the isolation strength, which results in surface creepage phenomenon, and the space breakdown phenomenon caused by the packaging metal structure of the two networks before and after the isolation in the space. In this paper, based on the idea of space geometry, the above physical phenomena are transformed: the space breakdown problem is equivalent to solving the linear distance between two points in space, that is, the Euclidean distance; The surface creepage problem is equivalent to the shortest connection distance between two points on the surface in solving space, that is, geodesic distance. By analyzing the position and length of the two paths, the electrical reliability of the packaged product is judged.

Using point cloud model to describe physical structure is an important means to transform the real physical world into a computable structure. 3D point cloud data can be generated by algorithm fitting or modeling software, which has the advantages of high precision, complete details and fast modeling speed. The spatial coordinates in the data are conducive to describing the spatial geometric relationship, and are widely used in many fields such as surveying and mapping, automatic driving, planning and design, electric power, architecture, industry, archaeology, medical treatment, games, and criminal investigation. There are two ways to transform 3D objects into point cloud model: forward and reverse. The former can directly transform 3D geometric model into point cloud model, so as to pre-analyze the product in the early stage of design; The latter can use lidar, depth camera and other equipment to obtain the appearance of the product surface and point cloud data for reverse analysis of existing products. In the actual modeling, the appropriate method should be selected according to the current state of the target.

In this paper, the microsystem structure is transformed into a point cloud model and then equivalent and calculation are carried out to realize the judgment and analysis of the potential breakdown risk inside the microsystem. In order to verify the effectiveness of the overall path, this paper will adopt both forward and reverse methods for modeling.

1. Point cloud modeling and analysis methods for Microsystems

1.1 Method of finding the shortest path

In point cloud model, in the path from one vertex to another vertex along the edge of the graph, the path with the smallest sum of weights of each edge is called the shortest path, which is a classic problem in graph theory. Dijkstra's algorithm adopts the breadth-first search strategy, expands outward with the starting point as the center, calculates the shortest distance from a single point to all points in the graph successively, and extends to the end point. It is an effective means to find the shortest path between the specified two points, and the calculation process can be summarized as follows:

(1) The starting point A is put into the set. The weight of point A is 0, because A->A=0;

(2) the weight of all points connected to the starting point A is set to the distance of the point A->, and the weight of the point that cannot be connected is set to infinity, find out the least weight B and put it into the set (at this time A->B must be the minimum distance);

(3) Repeat step 2 until all points are added to the set, and the shortest distance between all points and point A can be obtained.

The above process can find all possible paths to the target position in the microsystem model, ensure the comprehensive and accurate calculation results, and optimize the algorithm structure according to the actual situation of the model to improve the calculation efficiency.

1.2 Breakdown and creepage path calculation process

This paper uses PCL library to process point cloud data, mainly involving point cloud acquisition, filtering, segmentation, registration, retrieval, feature extraction, recognition, tracking, surface reconstruction and visualization. And according to the physical form of the microsystem, the shortest path calculation method based on Dijkstra algorithm is developed to simulate the breakdown and creepage phenomenon inside the microsystem. The calculation process is as follows.

(1) Three-dimensional model establishment. For products in design, the forward method can be adopted, that is, the three-dimensional structure at the time of design is successively converted into *.stl and *.obj grid files, and then the three-dimensional model is scanned in the form of rows and columns, and finally the *.pcd microsystem model including point cloud data is obtained; For existing products, the reverse method should be adopted, that is, the depth camera and other equipment microsystem can be used for high-precision scanning, and then the data can be converted into point cloud format for calculation and processing. This method fully restores the randomness in the process, and can fully show the real physical form of the product.

(2) Point cloud model transformation. To convert the three-dimensional model into a point cloud model, sampling can use uniform sampling and random sampling, the former is more suitable for products with regular shape, the latter has no requirements for the model and has more extensive adaptability.

(3) Point cloud model reading. In order to facilitate the subsequent partition processing, module identification and graphic display, it is necessary to color the pcl::PointXYZ type point cloud first, and convert it to the pcl::PointXYZRGB type point cloud with color attributes.

(4) Point cloud filtering. In order to better perform registration, feature extraction, surface reconstruction and other operations, it is necessary to first carry out point cloud filtering. In this paper, VoxelGrid filter is used to downsample the point cloud, smooth the point cloud data, filter outliers and reduce the size of the point cloud on the basis of maintaining the characteristics of the original data, so as to improve the efficiency of surface reconstruction and path calculation.

(5) Point cloud surface reconstruction. The filtered point cloud is still discrete data and cannot represent the appearance surface of the physical model. Therefore, it is necessary to reconstruct the surface of the point cloud model. In this paper, the greedy projection algorithm is used to rapidly triangulate the point cloud. First, the disordered point cloud is transformed into directed point cloud, and then the directed point cloud is reconstructed geometrically, so as to clarify the surface of the creepage path and the connection relationship between points on the surface.

(6) Point to point geodesic distance calculation. In this paper, Dijkstra algorithm is transformed according to the actual requirements in the microsystem. First, the vector container of std::vector class is converted into the connection relation of each point and all its adjacents, which is taken as the input parameter of Dijkstra algorithm; Then, define an equal-length vector container to store the sequence number of the nearest point to the above point; When all points are traversed, the location of the shortest path and the distance value of the path can be determined according to the sequence number in the container.

(7) equipotential surface division. Before calculating the geodesic distance, it is first necessary to determine the position of the conductive material where the starting and ending points are respectively located. Therefore, this paper calculates the linear equation of each line according to the polyline between the two equipotential surfaces. The point coordinates of the conductive materials in the point cloud are substituted into the equation to solve the problem, so as to divide each equipotential surface. And each equipotential surface is defined as a "group", in order to distinguish the potential of each part.

(8) The shortest path calculation from group to group, including Euclidean path and geodesic path between groups, is used to determine the shortest path between the two networks before and after isolation, and then judge the reliability risk of breakdown and creepage. First, the start group and the end group are marked according to the equipotential surface; Then, from a certain point of the starting group to find the nearest adjacency, judge whether the point belongs to the end point group, if not, then find the next adjacency, if yes, then mark the point as the end of the shortest path of the starting point, exit Dijkstra algorithm; Loop the last step until all the shortest path ends are found, where the shortest path is the shortest path of the two groups.

(9) Breakdown of the packaging metal structure. This paper uses the Euclidean distance from the isolated point groups on both sides to the cover plate and other structures, so the problem can be equivalent to finding the coordinates of extreme points in a certain direction within a group of point groups.

2. Point cloud computing case of microsystem breakdown and creepage

2.1 Simulation of substrate surface creepage path

Firstly, the effectiveness of the method is verified by pasting parallel copper strips on the glass surface, which satisfies the ideal equipotential and is close to the real microsystem in scale. At the same time, the errors and randomness in the process can be simulated to verify the accuracy of the algorithm. After that, modeling and simulation are carried out according to the above process. The simulation results show that the shortest distance in the structure is 217.264 pixels, 0.545cm after the physical distance is converted, the equivalent breakdown voltage is 6.31kV, and the error between the measured and 8%. The main reason is that the structure of the triangular surface is used in the reconstruction of the surface, and the path calculation must travel along the edge of the triangular surface, so the calculated path has the phenomenon of zigzag forward, and the overall error introduced by this is within the acceptable range. The verification model strongly proves the validity of the proposed method.

2.2 Microsystem substrate surface creepage path

The following takes a certain type of microsystem product as an example for analysis. Adopt the forward method to establish the front and back models of the microsystem substrate, and hollow out the metal layer on the surface of the substrate and the bottom of the pad, so as not to affect the path calculation, but also to increase the point density of the target area, and avoid the unreasonable phenomenon of “internal breakdown of the structure”. According to the above calculation process, the shortest path between the two isolated sides can be obtained, that is, the potential creepage path. Then, according to the process in the above example, the relationship between the surface creepage distance of the substrate material and the isolation voltage can be determined, and the current design can be judged that there is no creepage risk.

2.2 Breakdown behavior of interconnecting structure and metal shell

The breakdown risk between the interconnected structure and the metal shell is analyzed by taking the homotype microsystem as an example. The structure of substrate, bonding wire and connected chip, pad and pin is established, and the metal shell is equivalent to the space coordinate value to improve the calculation efficiency. The structure to the package shell includes the distance from the welding column to the edge, the distance from the bonding line to the top, and the boundary of the shell in the x and y directions is the boundary of the substrate; In the direction of z axis, take the upper surface of the substrate as the basis, and the upper 2.5mm is the shell. In this model, the bonding line height floats within a certain range, showing the randomness of the process. The sum of the distance between the two bonding lines and the cover plate in the vertical direction is calculated as the basis for judging whether the electrical spacing is satisfied.

Conclusion

In this paper, the point cloud analysis method and optimized Dijkstra algorithm are used to realize the analysis of the potential breakdown and creaking risk inside the microsystem, and a new solution to the pain point problem of the industry is proposed. The control experiment shows that the error between the simulation and the measured results is 8%, which fully demonstrates the effectiveness of this analysis method. Therefore, on this basis, we will continue to study the geodesic distance, physical modeling, algorithm acceleration, verification experiment and other aspects to improve the ability to analyze complex problems and expand the practical value of the software.

References:

[1].GuoYL,BennamounM,SohelF,etal.3Dobjectrecognitioninclutteredsceneswithlocalsurfacefeatures:asurvey[J].IEEETransaction SonPatternAnalysisandMachineIntelligence, 2014, 4 (11) : 2270-2287.

[2]. Jianwei Li,Jiawang Zhan. Research progress of 3D point cloud registration methods [J]. Journal of Image and Graphics, 2022,27 (02):349-367.

[3]. Xiang Zhang,Deyu Chen. Application of laser point cloud in 3D model reconstruction [J]. Laser Journal,2023,44(01):129-133.

[4]. Yanjin Du,Zhao Xu. Divisible and parallel reconstruction of massive point Clouds on Physical Surface [J]. Manufacturing Automation,2023,45(02):49-52+58.

[5]. Jie Yang,Xiaorong Wen,Qiulai Wang, etal. [J]. Journal of Northwest Forestry University,2022,37(06):129-137.

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