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Design and Analysis for the Y-axis Linking Part of PCB Drilling Machine

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Abstract

Aiming at the problem of the printed circuit board (PCB) Y axis linking part, we establish the 3D three-dimension model by using the Solidworks software, analysis the structure of the linking part and making appropriate solutions according to its works process and machining process. Finally, we use finite element method to analysis with COSMOSwork software to find the priory solution, improve the R&D speed, reduce processing costs and provide a reliable basis for the machine tool structure optimization design.

Keywords*: the Y-axis of the PCB drilling machine parts, the linking part of workbench, COSMOSwork finite element analysis*

1 Introduction

Nowadays, the pore size of the Printed Circuit Board (PCB) is more and more smaller (Φ0.1mm-Φ0.5mm), wiring density is more and more intensive (L(Line width)/S(Spacing): 0.1mm/0.1mm), drilling speed is faster and faster (150~200 Piercing/min) [1]; on the market, PCB CNC drilling machine from Switzerland has higher grade (pore size Φ0.1-Φ6.35mm, drilling accuracy ±0.02mm), followed are Germany and the United States, the third is Italy, Denmark and etc [2]; As for quality and price, the Japanese PCB CNC rig both has international advanced level and strong competitiveness. However, compared with the international drilling levels of the PCB CNC drilling machines, there is a great gap, which is still inefficient, single stage, defects in the structural design, structural optimization, link and combinations [3-5], so the research and development of new and efficient PCB CNC drilling machine has become an important goal for many company.

COSMOSworks is a set of finite element analysis software by the SolidWorks company devise. As embedded analysis software, it could seamlessly integrate with SolidWorks. COSMOSworks could help the ordinary engineer analyze and could quickly get results, so it shortens the product designing cycle to maximize, reduces testing costs, improves product quality, and increases profit margins [6]. This article is based on the SolidWorks 3D platform and COSMOSworks finite element analysis software, and the object is Y-axis table linking parts of PCB CNC drilling machine for researching the structure of the Y-axis.

2. Identifying Research Object

There are many PCB CNC drilling machines in the market whose specification is becoming increasingly diversified, among which single-axis, two-axis, four- axis, six-axis drilling machines have possessed mature technology. The working size of X-axis direction were divided into 520mm and 580mm (the travel of single spindle in X);While the Y-axis direction was 780mm(limited by the PCB standard size); As for driving, most of the time is servo motor driven ball screw, which locate in the middle of machine and on each side there are two rails, although four rails support workbenches may reduce the swing angle and improve the stiffness of the granite workbench, it increase the overconstraint and damping of the workbench at the same time, this makes the workbench need a long time to adjust when it is in high-speed motion adjust. Gantry structure frame made of bed and beams mainly played the supporting role in

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moving parts to absorb the vibration generated by moving mechanical parts, through this way to achieve the requirements of high stiffness, high damping and low thermal deformation in the machine. natural granite or artificial granite are used in domestic just now for granite is vibration absorption, dynamic characteristics, good insulation, high mechanical rigidity and low thermal expansion coefficient, etc. That is the reason we also use granite material as the Y-axis workbench [2]. Considering the future standardization of procurement, production, and the parts versatility of six-axis, four- axis, and two-axis CNC drilling machine, we taken the six-axis CNC drilling machine which consists the 580mm stroke X-axis and its Y-axis driving member are servo motor and a ball screw, materials of beds, beams and benches are all granite as the research object during this effort.

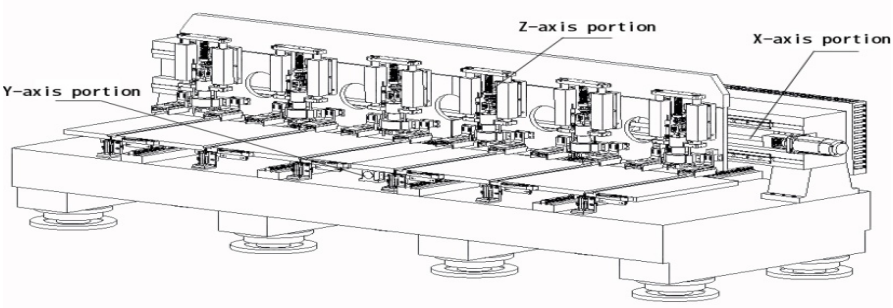

Figure 1. PCB CNC Drilling Structure Diagram

The portion of the Y-axis is the main object of this study; it is constituted by base, rail connection seats, the Y-axis rail, rail clamp bands, the Y-axis slider and slider connecting plate, left-right workbench and its connecting plate, clamping mechanism and so on. Driving part mainly consists of servo motor, ball screw and screw nut seat. In addition, there are manipulator mechanism, tool inspection mechanism, workbench shroud and rail shroud and so on. Apart from mechanical part, there are also electric parts, pneumatic and control parts. The mutual influence of these components should be considered when solving the problems of Y-axis .In the research process, we should consider actual machining accuracy, assembly precision, error range, machining process and the level of production, as well as the future requirements of standardization, universality, flow assembly. Also, we should reserve a certain space for the electric part, the pneumatic part placeholder, the placeholder of lines and water pipes.

3. Existing Problems and Analysis

The principle of structural optimization is reduce the quality of the bed body, simplify the mechanism, and enhance the rigidity of the components of the direct drive, improve the accuracy of the Y-axis displacement under the premise that punching accuracy is guaranteed. Now the problem is when Y-axis moves, the workbench has insufficient rigidity which caused the offset and result in drill not in the required positions, then lead to broken needles. Most severely, in the excessive high frequency drilling movement, the granite workbench produces cracks even rupture because of insufficient rigidity, which has a great influence on the quality of the drilling machine; Another problem is that, the stressed area of the intermediate connecting member is smaller, the connection process is too cumbersome, the assembly is not compact and inconvenient, it is likely to cause assembly errors; This not only increases the amount of assembly and connection parts, but also increases the weight of the bed, we have to improve the requirement of driver and select the high-power drive connected components, this will result in waste of money and makes the heavier Y-axis portion have a greater moment of inertia in the instant mobile, the instantly stress of granite workbench becomes greater; At the same time, ensuring the movement of rigidity and weight, we should optimize the structure of the key parts, simplify the general component structure and connections, reduce the assembly level, and optimize the overall performance [7].

The connection of the Y-axis: Basing on the assembly of four rail bearing, the rail connection seats mounting rails and the rail clamp bands(used to the fixed rail, to ensure the

straightness of the Y-axis direction), two Y-axis slider are installed on each rail and slider connecting plate is installed in the slider in order to increase the synchronization and rigidity of workbench, prevent cracks caused by insufficient rigidity of granite workbench; The Y-axis driving part (servo motor and ball screw) is mounted on the basing intermediate, servo motor is assembly in the base, Screw nut connects with workbench connection plate, the top of the table connection plate is the left-right workbench; The role of the workbench connecting plate is that, it links the right and the left workbench to drive, enhancing the rigidity and synchronization at the same time, it can prevent the right workbench and the left workbench swing; therefore, its structure is very important. The above assembly structure determines the height of the member of the Y-axis in the Z-direction space, however, This height of space is also influenced by the manipulator mechanism and tool inspection mechanism in front of the workbench, so we should reduce the space and ensure safety working space of the manipulator mechanism and tool inspection mechanism at the same time. In order to reduce the number of parts, decrease processing and procurement of parts, the Y-axis drive assembly space height and the X-axis drive assembly space height must be consistent, and then the center height of screw is consistent, so the components associated with the drive are universal.

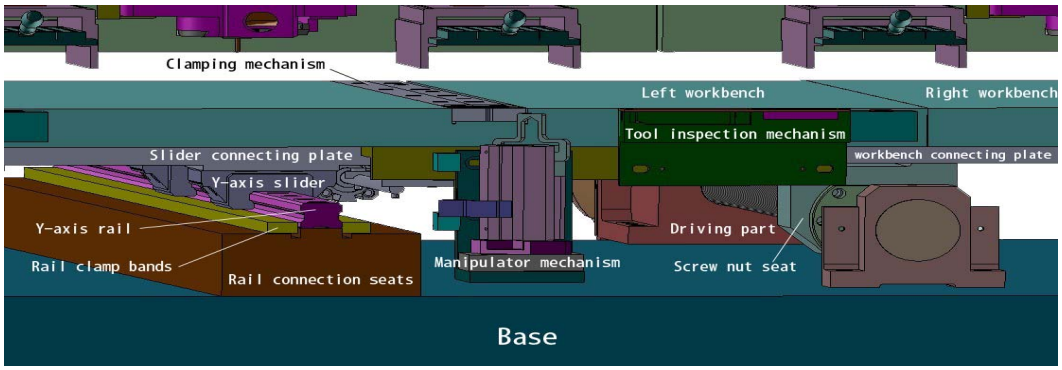

Figure 2. 3D Assembly Drawings of the Major Part of Y-axis

In order to improve the accuracy of the displacement of the Y-axis driving, first we must solve the problem of reducing linking process, which includes driver and the major driving components, it makes the driver directly link with the main drive members, the workbench is mainly driven member. Screw nut seat is the major drive component, the sliders are auxiliary drive components, we can omit the slider connecting plate and table connection plate, directly link screw nut seat and slider with the workbench, this can reduce the space height.

It is feasible that slider directly link with the table, however, whether screw nut seat can be directly connected with the workbench or not? Through our analyze, screw nut seat can be directly connected with the workbench, due to the small area of the contact area of both relative workbench, if the granite workbench with insufficient rigidity is connected directly together, it easily to cause cracks, so this method is not feasible; so we should increase the contact area of workbench and the screw nut seat, simplify screw nut seat and workbench connecting plate to a part. But the contact area of the screw nut seat is 101.4cm^2, workbench connecting plate connect surface area is 802cm^2 (when worked as connecting the right and left workbench), the area is a larger compare with screw nut seat parts. If it is as one part, there will be a big problem of machining and assembling. It can not guarantee the processing and assembly precision, so it is not feasible either; Finally, we will change the structure of the workbench connecting plate, increase contact area of the connecting plate of the workbench, then lengthen X symmetrically, increase the force strength of workbench connecting plate, it improves the left and right parallelism of the workbench, reduces Y axis swing of right and left workbench, so improve the overall rigidity. Therefore, we have determined to omit the slider connecting plate and optimize workbench connecting plate.

The workbench connecting plate structure optimization, we should take the effects of processing technology, assembly and other parts into account; First of all, to extend in the X-

axis direction, it must not affect the slider, the slider clamp bands, the manipulator mechanism, tool inspection mechanism and clamping mechanism, it should ensures the force area and maximizes the contact area, ensures the driving rigidity requirements and the granite force range. The following is a bench on the back parts assembly diagram;

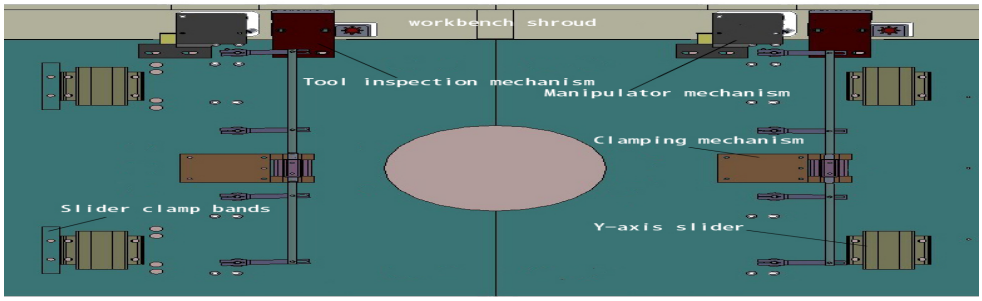

Figure 3. The Parts Assembly Diagram of the back of workbench

4. Theoretical Data Analysis

Now, it is a smaller contact area between the workbench connecting plate and workbench, force distribution are concentrated, the driving force can not be extended, this causes the workbench places far away from the drive member with move lag, poor rigidity of the Y-axis and swing around, simple structure only play a connective role, with poor functionality; in order to expand the driving force to a wide range of areas it should widening deepening. Now we widen and deepen it, make the driving range of driving force becomes larger, consequently it is not only become a connection, but also playing a role in supporting and balancing right and left workbench, for materials the best choice is castings (HT200) which makes the process is easier. The size should not exceed the workbench, and it can not interfere with other parts, the quality is less than 50kg (Over-weight will impact the center high of screw), it should meet some requires, for example the structure is easy to cast, easy to processing and easy to handle, especially, the most important is that the force is good, strong rigidity, and so on.

In order to prevent the phenomenon of back and forth swing caused by the right and left workbench unsynchronized moving, it extended to the slider. For the drive force from the Y-axis direction, increase the driving force area and enhance the synchronization, Widen the contact active surfaces area of Y direction and the screw nut seat, improve the mechanical parts rigid, thus improve the overall performance of the workbench. The Y-axis drive motor is AC permanent magnet synchronous servo motor, Rated Power **P**=4kw, Rated speed **n**=3000/min, Maximum speed is 4500/min, Positive efficiency of the ball screw **η**=0.94, Screw lead **Ph**=10mm, friction coefficient **μ**=0.1. The overall quality of the workbench part is about 400kg (**Fa**), **g**=9.8m/s2. Motor rotates with constant speed and workbench horizontally moves.

Rated drive torque of motor:

$$T_1=(9550*P)/n=12733N.mm$$

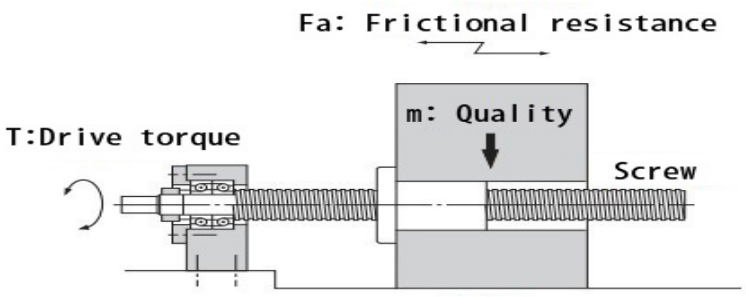

Figure 4. The force distribution diagram of ball screw

The required torque of the balls crew load:

$$T=Fa*Ph/(2*3.14*\eta)$$

$$Fa=\mu*mg$$

$$T=677N.mm$$

The T_1 is much larger than T, through the adjustment of the coupling; motor meets the needs of transmission thrust torque. This demonstrated that the overall quality of all connected components above the workbench does not have a big impact on the run of the ball screw; it does can guarantee the accuracy of the ball screw on Y direction.

5. Finite Element Analyses

Compared with other similar software, there are many features of the COSMOSworks finite element analysis software; it has lower performance requirements of the computer and convenience for popularization and application [8-11]. First of all, we click the “Assess” in the select of the menu bar →“COSMOSXpress”, started the COOSMOSXpre as wizard. And follow these steps: material selection ---- add constraint surface ---- add load ---- run ---- meshing ---- optimize parts ---- view results. Here are two workbench connecting plate designs and finite element analysis process.

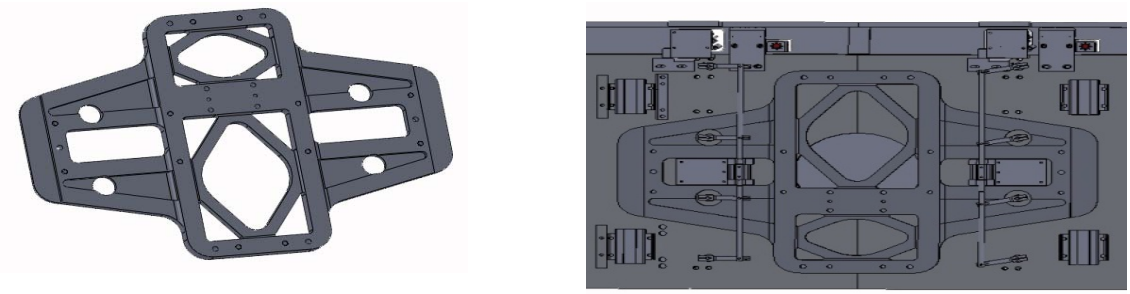

Figure 5. the Option I View of the Workbench Connecting Plate (Material: HT200; Weight: 39.4kg)

The structure of the design increased quality and improved the rigidity of the Y-direction, increased the force area and raised the workbench driving force, enhanced the stability of the left and right workbench, added more connecting holes, increased tightness of its linking, made the hierarchical structure more compact. The following are the centralized distribution map of stress and the variable value of generating displacement:

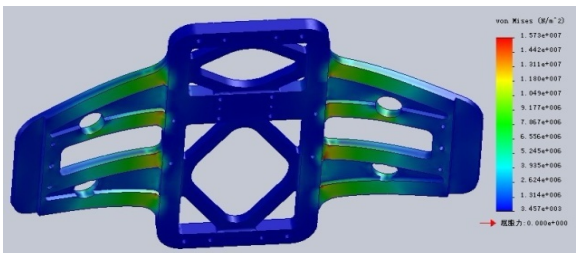

Figure 5.1. The Force Distribution Diagram of Z Direction

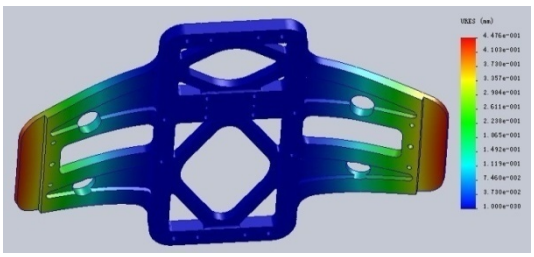

Figure 5.2. The Amount of Deformation Distribution Diagram of Z Direction

Analysis shows that the Maximum offset of Z direction is 0.447601 mm, the Maximum stress is 1.57296e+007N/㎡, it is mainly on both sides and meet the actual requirements. Here is the stress analysis of the screw nut seat and worktable link board stress analysis, it is mainly for

the Y-axis direction by the force, the following is the force distribution diagram and the amount of deformation distribution diagram:

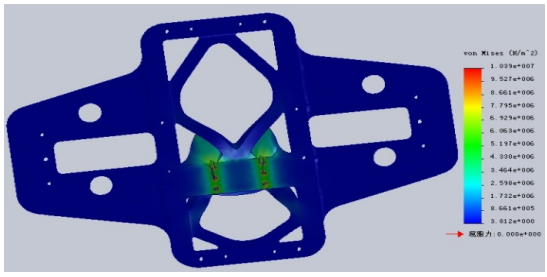

Figure 5.3. The Force Distribution Diagram of Y Direction

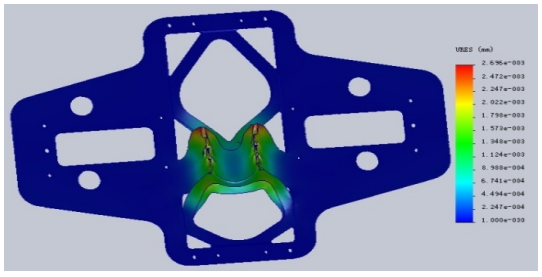

Figure 5.4. The Amount of Deformation Distribution Diagram of Y Direction

Analysis shows that the Maximum offset of Y direction is 0.00269648 mm and the Maximum stress is 1.03931e+007 N/m^2, Which meet the actual requirements.

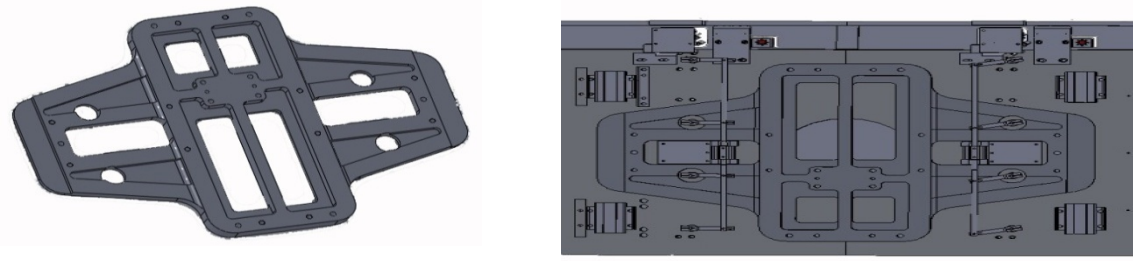

Figure 6. The Option II View of The Workbench Connecting Plate (Material: HT200; Weight: 39kg)

This improvement is mainly for the workbench internal structure, from a diamond structure changed to a cross structure. Such changes has made the force in the XY direction concentrate on the support shaft, which reduced the internal amount of the holes caused by the main force, enhanced internal rigidity and improved the overall stability of the structure. The following is the centralized distribution map of force and the variable value of generating displacement:

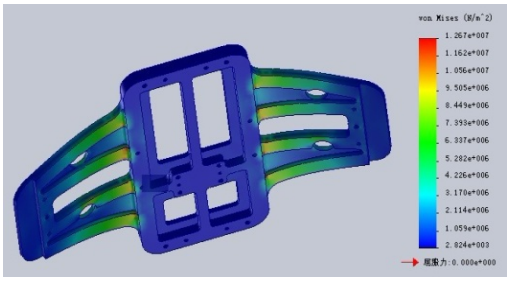

Figure 6.1. The Force Distribution Diagram of Z Direction

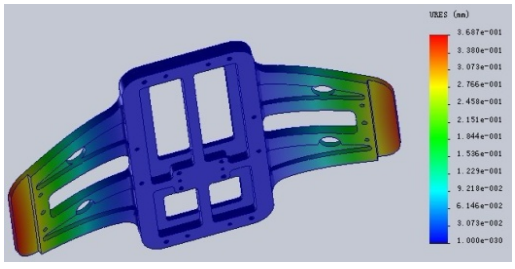

Figure 6.2. The Amount of Deformation Distribution Diagram of Z Direction

Analysis shows that the Maximum offset of Z direction is 0.368736mm, the Maximum stress is 1.26718e+007 N/m^2.

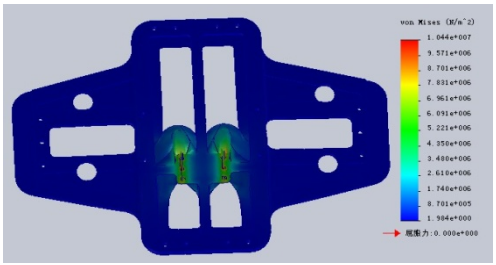

Figure 6.3. The Force Distribution Diagram of Y Direction

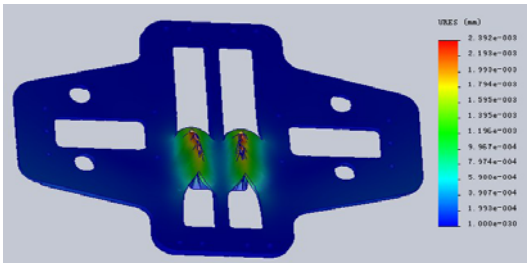

Figure 6.4. The Amount of Deformation Distribution Diagram of Y Direction

Analysis shows that the Maximum offset of Y direction is 0.00239211mm, the Maximum stress is 1.04411e+007N/㎡

Compared with the two programs, we can know that the weight of the Option II reduced 0.4kg, decreased the Offset and maximized the larges tress. It also reduced the impact of the punch accuracy on the work, so we select Option II as the final structure.

6. Actual Test Analysis

According to the actual operation, we installs Option II workbench connecting plate in the actual PCB drilling machine, we can make use of the relevant testing software to get the following results.

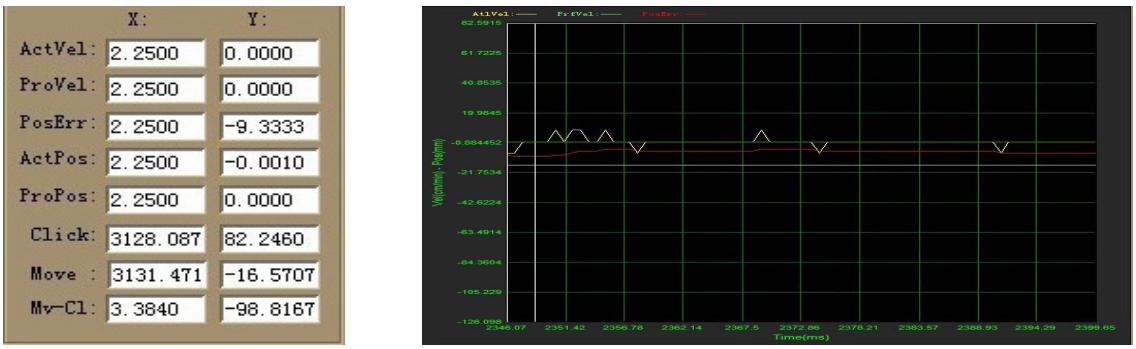

Figure 7. The Graph of Y-axis Moving Displacement Error

The red line is the Y axis error value curve. The intersection of the two white lines above the red line segment deviation from the origin has the farthest distance, which is the maximum error value. It is caused by inconsistent of the command speed and actual speed. This problem can not be avoided; just can adjust the structure of this error to the minimum(Less than 10^{-3}mm).

We can get that the maximum displacement of the Y-axis deviation is 0.0093333mm (Less than 10^{-3}mm). When drilling machine is steadily working, the displacement error is less than 0.0093333mm. When the machine works, this ensures the synchronization and the accuracy of the right and left workbench, which makes high accuracy of the drilling. Therefore, the role of the program workbench connecting plate is critical.

7. Conclusion

According to the test results of the printed circuit board drilling machine, we know the Option II can meet the rigidity conditions of the drilling machine Y-axis table, Offset, maximum stress, as well as the deviation amount of the Y-axis of the drilling machine in the allowance. So the method of combination of theoretical analysis and three-dimensional simulation of finite

element analysis is feasible and effective. It greatly helps designers improve efficiency and reduce the cost of the company's test. It has high reliability. So we have learned a lot in the course of the research. When considering the problem, we should stand in someone else's (Processing workers, assembly workers, operation workers, maintenance workers) point of view, and design more competitive and user-friendly mechanical products.

Acknowledgment

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