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A Review on Experimental Analysis of Protective Coating Used During Micro Drilling of PCB

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***Abstract*: A printed circuit board (PCB) mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from copper sheets laminated onto a non-conductive substrate. PCBs can be single sided (one copper layer), double sided (two copper layers) or Multi-layer (outer and inner layers). Multi-layer PCBs allow for much higher component density. Conductors on different layers are connected with plated-through holes called vias. Advanced PCBs may contain components- capacitors, resistors or active devices – embedded in the substrate. Glass epoxy is the primary insulating substrate upon which the vast majority of rigid PCBs are produced. A thin layer of copper foil is laminated to one or both sides of panel. Circuitry interconnections are etched into copper layers to produce printed circuit boards. Complex circuits are produced in multiple layers. Printed circuit boards are used in all but the simplest electronic products. The main function of PCB is to transfer electricity and produce an opening through the board that will permit a subsequent process to form an electrical connection. For that purpose, quality of hole should be good, Micro drilling required high speed and high force due to that top surface of PCB material get damaged. To avoid this damage protective entry material is used. By conducting the experiments on four different materials we will finalized the material suitable for PCB drilling. The analysis is based on cost and process. The ANOVA technique is used for optimization of process parameters.**

***Keywords*: PCB, Entry material, ANOVA.**

1. Introduction

Printed circuit boards evolved from electrical connection systems that were developed in the 1850s. Metal strips or rods were originally used to connect large electric components mounted on wooden bases. In time the metal strips were replaced by wires connected to screw terminals, and wooden bases were replaced by metal chassis. But smaller and more compact designs were needed due to the increased operating needs of the products that used circuit boards. In 1925, Charles Ducas of the United States submitted a patent application for a method of creating an electrical path directly on an insulated surface by printing through a stencil with electrically conductive inks. This method gave birth to the name "printed wiring" or "printed circuit."

In the 1943, Paul Eisler of the United Kingdom patented a method of etching the conductive pattern, or circuits, on a layer of copper foil bonded to a glass-reinforced, non-conductive base. Widespread use of Eisler's technique did not come until the 1950s when the transistor was introduced for commercial use. Up to that point, the size of vacuum tubes and other components were so large that the traditional mounting and wiring methods were all that was needed. With the advent of transistors, however, the components became very small, and manufacturers turned to printed circuit boards to reduce the overall size of the electronic package. Through hole technology and its use in multi-layer PCBs was patented by the U.S. firm Hazeltyne in 1961. The resulting increase in component density and closely spaced electrical paths started a new era in PCB design. Integrated circuit chips were introduced in the 1970s, and these components were quickly incorporated into printed circuit board design and manufacturing techniques.

2. Literature Review

A. Part I: Papers related to coating material

Lukas Pilny, Leonardo De Chiffre, Miroslav Píška, Morten F. Villumsen, [1], The characteristics of carbon fibre reinforced laminates have widened their use from aerospace to domestic appliances, and new possibilities for their usage emerge almost daily. In many of the possible applications, the laminates need to be drilled for assembly purposes. It is known that a drilling process that reduces the drill thrust force can decrease the risk of delamination. In this work, damage assessment methods based on data extracted from radiographic images are compared and correlated with mechanical test results bearing test and delamination onset test and analytical models. The results demonstrate the importance of an adequate selection of drilling tools and machining parameters to extend the life cycle of these laminates as a consequence of enhanced reliability.

K. S. Aithal, Y Narahari and E Manjunath [2], Product design and fabrication constitute an important business activity in any manufacturing firm. Designing an optimized product fabrication process is an important problem in itself and is of significant practical and research interest. In this paper, we look into a printed circuit board (PCB) fabrication process and

investigate ways in which the fabrication cycle time can be minimized. Single class queueing networks constitute the modeling framework for our study. The model developed in this paper and the analysis experiments carried out are based on extensive data collected on a PCB fabrication company located in Bangalore, India. This is a representative PCB fabrication company involving multiple, concurrent fabrication works with contention for human/technical resources. Our model seeks to capture faithfully the flow of the fabrication process in this company and such other organisations, using queueing networks. Using the model developed, we explore how the cycle times can be reduced using input control, load balancing, and variability reduction. The model presented is sufficiently generic and conceptual; its scope extends beyond that of a PCB fabrication organization.

L. M. P. Duraoa, A. G. Magalhaesa, A. T. Marquesb, Joao Manuel R. S. Tavaresb [3] Composites are more and more increasing their importance as one of the most interesting group of materials, because of their unique properties. Hole drilling operations are common in composite parts to facilitate fastener assembly. As composites are non-homogeneous this operation causes some damages like delamination and others that reduce bearing and fatigue strength of the composite part. A proper selection of tool and drilling parameters can reduce the risk of delamination. In this paper three cutting speeds, three feed rates and three tool geometries are compared. Conclusions show the influence of an adequate selection of tool and cutting parameters in delamination reduction.

V. Santhanam, M. Chandrasekaran [5], Composite materials are used in many engineering applications due to their superior properties. Hybrid fibre composites are developed to provide the advantage of both natural fibre and synthetic fibre. Drilling is an inevitable task for component assembly. Studies on drilling performance of Banana-Glass fibre hybrid composite is reported in this article. Banana-Glass fibre reinforced Epoxy composites were prepared by using hand layup method. Drilling experiments were conducted on chopped fibre and laminated woven fibre composites using standard twist drill. Experiments were conducted by varying the feed rate and speed. The Effect of fibre volume fraction in chopped fibre and stacking sequence in woven fibre composite on the drilled hole quality was found. Optimum drilling parameters were determined for selected samples each from chopped fibre and woven fibre composite. Machine vision technology was used to measure quality of the drilled Hole. ANOVA technique was used to analyse the experimental data and it was found that the feed rate has major influence than drilling speed on the hole quality.

B. Part II: Papers related to drilling parameters

Hidehito Watanabea, Hideo Tsuzakaa, Masami Masudab [6], Drilling is a cutting process that uses a drill bit to cut or enlarge a hole of circular cross-section in solid materials. The drill bit is a rotary cutting tool, often multipoint. The bit is pressed against the work piece and rotated at rates from hundreds to thousands of revolutions per minute. This forces the cutting edge against the work piece, cutting off chips (swarf) from the hole as it is drilled. Here we are analyzing the drilling tool life, which showed us that there are different parameters (Force, feeding Rate, MOQ, Tool Material, Tool Geometry, etc.), which are affecting the Drilling Tool Life.

R. M. Kulkarni, H. N. Narasimha Murthy, G. B. Rudrakshi, Sushilendra [8], This paper focused on investigating the effects of drilling parameters like spindle speed (600rpm, 1860 rpm and 2700 rpm), Feed rate (0.1mm/rev, 0.2mm/rev and 0.3mm/rev), drill point angle (1180, 1100 and 900), drill material (HSS, Co-HSS and Tungsten Carbide) and carbon black (0, 4 and 8 wt %) on the responses: thrust force and delamination factor (entry and exit) in drilling of carbon black dispersed vinyl ester GFRP, by Design of Experiments approach. Drilling experiments were designed to control the drilling parameters based on L27Orthogonal Array. The experimental results were analyzed using MINITAB V16. Signal-to-Noise (S/N) ratio, ANOVA and Grey Relation Analysis (GRA) were employed to analyze the effect of drilling parameters on the quality of the drilled holes. Minimum value of thrust force was obtained for 4 wt% carbon black, 2700 rpm, 0.1 mm/rev, 1100 drill point angle and HSS drill. Delamination was minimum for 4 wt% carbon black, 2700rpm, 0.1mm/rev, 4mm diameter with Tungsten Carbide (WC) drill. SEM confirmed that delamination at the exit is greater than delamination at the entry.

Elias George K, Varadarajan A.S, Rani Joseph [7] Drilling is an essential operation in the assembly of the structural frames of automobiles and aircrafts. The life of a joint can be critically affected by the quality of the drilled holes. Drilling of composite materials is significantly affected by damage tendency of these materials under the action of cutting forces (thrust force and torque). Composite laminates of three different types were fabricated by using E-glass fiber and epoxy resin in the laboratory. The trials as per the design of experiments were performed using Taguchi method. The results indicate that composite prepared with a randomly oriented fiber mat (chopped strand mat) gives the best hole with the least value of damage factor at a spindle speed of 450 rpm and at a drill tool angle of 110˚. Further, it is found that the peak torque and thrust force required for this combination are in their minimum levels.

Azlan Abdul Rahman, Azuddin Mamat, Abdullah Wagiman. [4]. This paper presents the effect of drilling parameter such as spindle speed, feed rate and drilling tool size on material removal rate (MRR), surface roughness, dimensional accuracy and burr. In this work, a study on optimum drilling parameter for HSS drilling tool in micro-drilling processes in order to find the best drilling parameter for brass as a workpiece material. Micro drilling experiment with 0.5 mm to 1.0 mm drill sizes were performed by changing the spindle speed and feed at three different levels. The results were analyzed using microscope and surface roughness device. Comparatives analysis has been done between surface roughness, MRR and accuracy of drilled holes by experimentation. From the result, the surface

roughness is mostly influenced by spindle speed and feed rate. As the spindle and feed rate increases, the surface roughness will decrease. The tool diameter gives less influence on the value of surface roughness. The value of MRR is decreased when the tool diameter, spindle speed and feed rate are decreases. As drilling tool diameter, feed rate and spindle speed increase the dimensional accuracy of drilled hole will decrease. The increment of spindle speed and feed rate value mostly will affect the tool wear and size of burr on the edge of drilled holes.

C. Part III: General papers

Hae-Sung Yoona, Jong-Seol Moona, Minh-Quan Phama, Gyu-Bong Leeb, Sung-Hoon Ahn.[9], Over the past half-century, numerous concerns pertaining to energy consumption and environmental factors have emerged, together with a strong demand for energy conservation in the industrial sector. The aim of this research is to develop new models and methodologies to control the energy consumption and manufacturing costs in the micro-drilling process for printed circuit board manufacturing. In micro-scale machining, the energy involved in material removal is negligible compared to the energy consumed by the machine modules. A set of experiments was performed to collect data on the energy consumption of the machine modules and their tool life. The results clearly identified the energy consumption and manufacturing cost trends in terms of the process parameters. Faster machining can reduce the energy consumption, but increases the cost. Considering only the cost aspect of the drilling process, 35% of the manufacturing cost can be saved. Using the proposed model, operators can select the appropriate process parameters by considering the conflict between minimum energy and minimum cost criteria, as well as local conditions.

Aykut Kentli.[10] states that this study investigated the effect of cutting speed, pecking depth and feed rate on drilling of glass fiber reinforced polymer composite materials. Glass fiber reinforced polymer composite parts has been started to get extensively used at the industry of space, aviation, ship, chemistry and automotive nowadays. Other than these fields of usage, at processing composite parts by machining, some problems have been revealed due to the anisotropic structure that the composite materials have. Drilling-induced damage is a serious problem in laminated composite materials. The worldwide research and development efforts have been focused on the area, but a few numbers of studies have investigated peck drilling. In this study, the effect of the above mentioned parameters was investigated and damage factor was estimated using Artificial Neural Network. The artificial neural network topology has been adopted as a predictive tool. The feed rate, cutting speed, pecking depth and damage place have been used as the input parameters. The drilling-induced damage was the output. The experimental data for drilling of woven glass-fiber-reinforced plastic composite laminates were used for training and testing the model. The results of the predictive model have been found to be in good agreement with the test data.

Azlan Abdul Rahman, Azuddin Mamat, Abdullah Wagiman [13], This paper present the effect of drilling parameter such as spindle speed, feed rate and drilling tool size on material removal rate (MRR), surface roughness, dimensional accuracy and burr. In this work, a study on optimum drilling parameter for HSS drilling tool in micro-drilling processes in order to find the best drilling parameter for brass as a workpiece material. Micro drilling experiment with 0.5 mm to 1.0 mm drill sizes were performed by changing the spindle speed and feed at three different levels. The results were analyzed using microscope and surface roughness device. Comparatives analysis has been done between surface roughness, MRR and accuracy of drilled holes by experimentation. From the result, the surface roughness are mostly influenced by spindle speed and feed rate. As the spindle and feed rate increases, the surface roughness will decrease. The tool diameter gives less influence on the value of surface roughness. The value of MRR is decreased when the tool diameter, spindle speed and feed rate are decreases. As drilling tool diameter, feed rate and spindle speed increase the dimensional accuracy of drilled hole will decrease. The increment of spindle speed and feed rate value mostly will affect the tool wear and size of burr on the edge of drilled holes.

Kiha Lee, Ingo Essel, David A. Dornfeld [11], This paper describes the experimental studies on micro-milling in aluminum 6061-T6, stainless steel 304 and copper 110 have been carried out. A range of different cutting chip loads and depths of cut using 127µm, 254µm and 635µm diameters were considered. The influence of the cutting parameters on burr size and burr type was observed. A comparison to burr formation in different materials is presented.

Elias George K, Varadarajan A. S, Rani Joseph [10], This paper describes that The Printed Circuit Board (PCB) is the backbone of electronics and a large number of consumer devices. The challenge to put more function in a smaller space requires more components utilizing smaller bond pads, smaller lines and tighter pitch. The electronic packaging industry has aggressively pursued novel ways to shrink and stack multilayer boards inside smaller volumes. Industry is approaching serious obstacles in the continued size reduction requirements with the need for wires, epoxy, vias, solder and sometimes bolts and screws to mount the boards. The next logical step is to move beyond 2D stacking, which is 2.5D to make 3D packages and to utilize the 3rddimension directly. Eliminate the traditional 2D FR4 board and the wires, epoxies, vias and solder and make the next generation packages utilizing the 3rd dimension; the Printed Circuit Structure (PCS). The PCS concept will allow passives, actives and even antennas to move out of the XY plane and into the XZ and YZ planes. This new dimension will appear to be very complex and next generation circuit optimization will be required, but the end result will net a significant improvement in volume utilization. In addition, if new materials are developed and utilized properly, the PCS will be the box or the package thus eliminating all the bolts and screws necessary to mount a PCB in a traditional box or package, thus

again saving space and reducing weight. nScrypt and the University of Texas at El Paso will present 3D Printing of Printed Circuit Structures. A demonstration of true 3D electronic structures will be demonstrated and shown as well novel approaches which utilize Computer Aided Design (CAD) to 3D Printing which will include the electronics portion.

3. Conclusion

This paper presents an overview on experimental analysis of protective coating used during micro drilling of PCB.

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