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Analysis of Stresses in Microdrills

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Abstract* – The trend towards high density printed circuit boards requires smaller holes to 0.1mm diameter to be drilled through the board layers. A 0.1mm drill is used to produce holes in a PCB of thickness 0.5mm. The board is fabricated with standard glass fibers and copper layers on both sides. Drills of this size are inherently more susceptible to drill breakage and must be used with restricted operating parameters. The most common cause of failure of small drills is breakage and that dill breaks as a result of either two great a thrust force (or) too great a torque. In order to analyses the stresses occurring in micro drills finite element methods are used. Three dimensional models of drills are made using CATIA of the drill geometry. The first drill is designed with point angle 114^0 and the second drill is designed with point angle 116^0. Measured results from experimental tests are used to determine drill loading. Principle stress isograms on drill cross-sections are presented for different drill geometry and correlation with actual drill life is made.

Index Terms: **Stresses, PCB (printed circuit boards), Flute length, Helix angle, Micro drill, Point angle.**

I. INTRODUCTION

Micro drilling is characterized not just by small drills but also a method for precise rotation of the micro drill and a special drilling cycle. In addition, the walls of a micro drilled hole are among the smoothest surfaces produced by conventional processes. This is largely due to the special drilling cycle called a peck cycle. The smallest micro drills are of the spade type. The drills do not have helical flutes as do conventional drills and this makes chip removal from the hole more difficult. Drills with a diameter of 50 micrometers and larger can be made as twist drills [1]. Drills smaller than these types are exclusively of the spade type because of the difficulty in fabricating a twist drill of this size.

There are several important geometric characteristics of spade-type micro drills. First, the point of the drill is not a point at all. Even on conventional twist drills, the end is not truly pointed. Instead, the end of the micro drill consists of a cutting edge (called the chisel edge) made by two intersecting planes which also define the two primary cutting edges of the drill. The chisel edge removes material primarily by extrusion and cutting at high negative rake angle. The specific cutting energy along the chisel edge is relatively large compared to the drill's primary cutting edges. The chisel edge also adds to the drilling complexity because of the lack of a point. As the rotating drill first contacts the work piece (remember the drill has a very small structural rigidity) anything on the surface, including micro roughness and material slope, will cause the drill to walk on the surface as it is trying to begin removing material [9].

Micro drilling has one major disadvantage because of the drill geometry. Because of the drill point, a flat-bottomed hole can not be produced. If one is attempting to produce cylindrical cavities in a micro mold, there must be a relatively thick plating base under the mold material, or the structural substrate of the mold could act as the plating base [7]. To fully develop the diameter of the hole, projected onto a plane perpendicular to the drilling direction, requires the drill point to extend 30% of the drill diameter beyond the depth of the fully developed hole. For holes in the 100 micrometer region, requires a thick plating base to be deposited. One method for creating flat-bottomed blind holes is to use an end milling tool instead of a drill. The disadvantage to this procedure is that drills have a typical L/D ratio of 4 to 14 while end mills typically have a ratio of only 1.5 to 3. Mechanical micro drilling advances the architecture of drilling machines and bits has improved significantly over the past few. In printed circuit boards (PCB) drilling small holes through the thickness of a board is part of the process of making connections between the layers [8]. Subsequent plating processes deposit copper conduction paths on the side of the hole. The term micro drilling here refers to the mechanical drilling of hole diameter down to 0.1mm that currently represent the feasible lower limits of this technology for PCB manufacturer. In the not so distant past, 0.20 mm mechanically drilled holes were considered state-of-the-art. In the past few years, however, a great deal of effort has been devoted to small hole drilling to improve the drill

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hole quality, drill life and hole location accuracy. Micro drilling has prompted machine manufacturers and drill bit suppliers to change basic product designs to accommodate this important and indispensable technology [3]. Today, drilling 0.20 mm in a two-panel stack is almost a routine occurrence, and many manufacturers make high-quality holes using micro drilling techniques in full production [5].

II. PROBLEM FORMULATION

Micro drill bit is design and analysis to determine the stress distribution over the drill bit.
The work will be divided in three parts

- Development of 3D drill model
- Analysis of the model in Ansys 10
- Comparison of results

The Geometric features of micro drills are diameter, Flute length, Helix Angle, Web thickness, Point Angle, Chisel Edge Angle etc [6]. The Geometric features of micro drills for my project are

Table 1: Geometric feature of micro drills

Geometric features	Drill 1	Drill 2
1. Diameter	0.1mm	0.1mm
2. Flute length	1mm	1mm
3. Body length	1mm	1mm
4. Helix Angle	30^0	30^0
5. Web Thickness	0.03mm	0.03mm
6. Point Angle	114^0	116^0
7.Chisel Edge Angle	62.5^0	62.5^0
8. Web Taper	1.7^0	1.7^0

- The first drill is developed with point angle 114^0
- The second drill is developed with point angle 116^0

A. PROCEDURE TO ARRIVE 3D MICRODRILL MODEL

In CATIA software, under part, the solid cylindrical Model of the drill is made using revolve option. Then to obtain helix angle, a curve is made along the axis of the drill using curve option.
To obtain the curve, the following equations are used.

D = 0.05; M = -1; N = 1

X = d* cos (n*t*360) ; Y = d* sin (n*t*360); Z = m* t

Using cut and swept blend option, the helical cut is made on the cylindrical part of the drill for given dimension.
Using pattern plane option create chisel edge angle for 62.5^0
Using cut option obtains the point angle. Using tweak and draft option tilt the lip to the required dimension. Thus 3D Model of the micro drill for the given dimension is made.

B. ANALYSIS OF THE MODEL

Analysis of 3d Micro Drill with Point Angle 114^0

DRILL MATERIAL: TUNGSTEN CARBIDE:
Tungsten Carbide – 93.5 – 94.5%
Cobalt - 5.5 – 6.5%

Physical Properties: Specific Gravity – 15.00 Nominal
Density (Approx) - 0.54 lbs/in3

Mechanical Properties: Ultimate Tensile strength – 1516.84 Mpa
Ultimate Compression strength – 5171.06– 5446.8 Mpa
Transverse Rupture strength –2206.3– 2516.5 Mpa
Hardness Rockwell – A89 – 92
Modulus of Elasticity – 634317.83– 641212.5 Mpa
Poisons Ratio – 0.26
Maximum Useful temperature – 800 F
Magnetic Property – Slightly Magnetic

Target Material – Copper: Type – C110
Ultimate tensile strength – 331 Mpa

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Yield Strength – 310 Mpa
Shear Modulus – 44.7 e3 Mpa
Young's Modulus – 108e3 Mpa
Density – 8885 kg/m3
Hardness (Vickers) – 92

Selection Parameter for Analysis:

End Load – 0.56 N
Torque – 0.015 N-mm.

The above Mentioned data are collected from the journal Machine Tools & Manufacture for micro drill analysis [2, 10]. This Load and torque are applied to the model of the Drill 1(with point angle 114^0 & 116^0) and then the analysis is carried out the results are shown in Fig. 1 to 8.

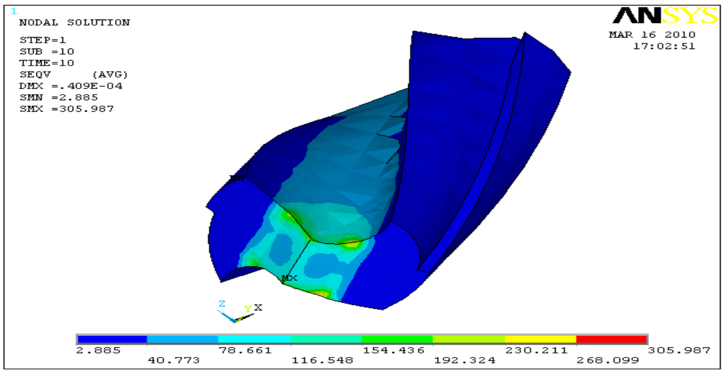

Fig. 1: deformation of the micro drill at 114^0

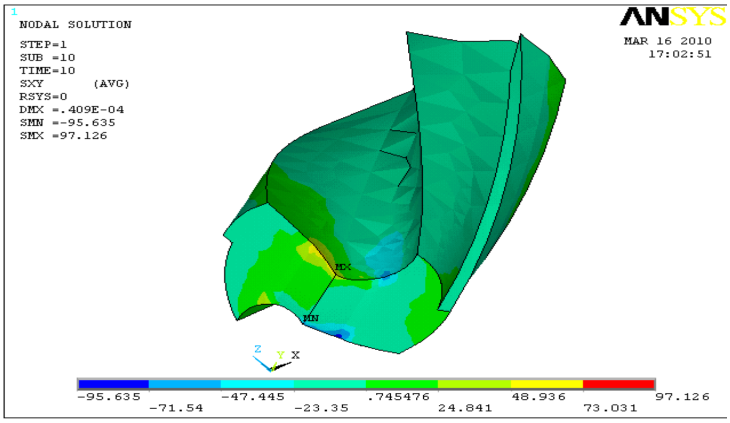

Fig. 2: shear stress distribution in xy direction at an angle of 114^0

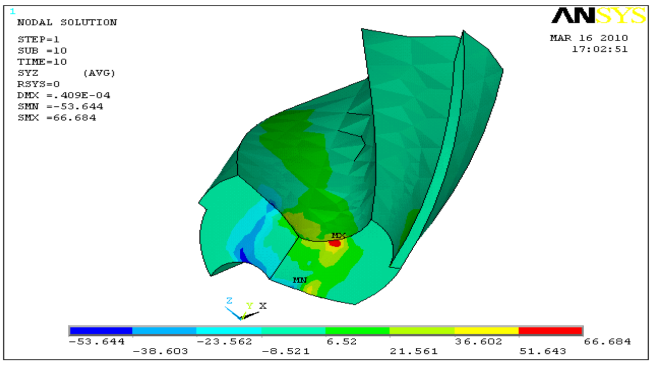

Fig. 3: shear stress distribution in yz direction at an angle of 114^0

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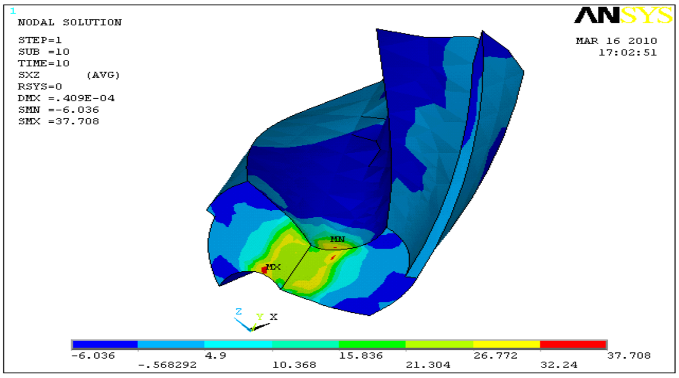

Fig. 4: shear stress distribution in xz direction at an angle of 114^{0}

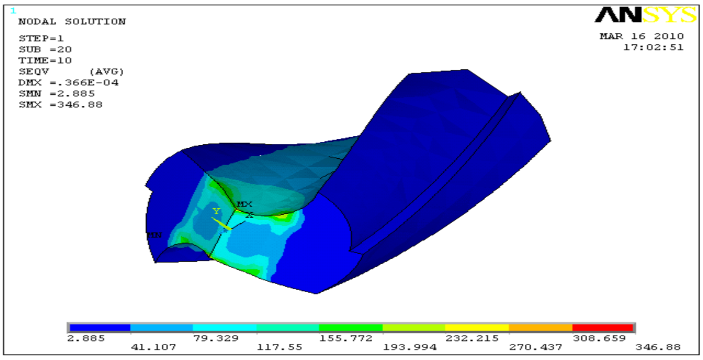

Fig. 5: deformation of the micro drill at an angle of 116^{0}

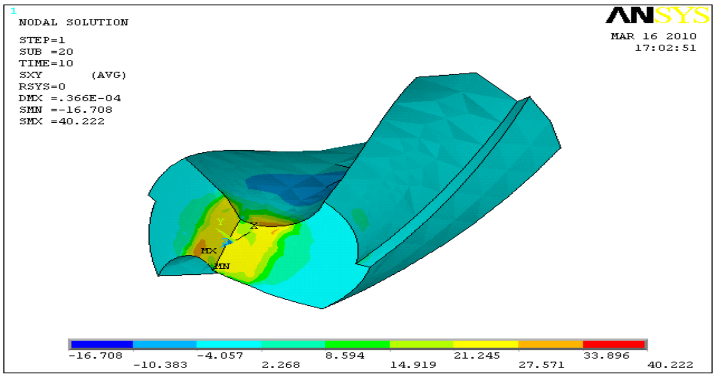

Fig. 6: shear stress distribution in xy direction at an angle of 116^{0}

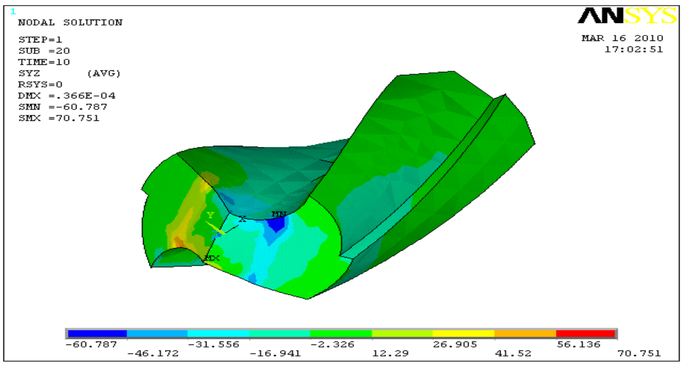

Fig. 7: shear stress distribution in yz direction at an angle of 116^{0}

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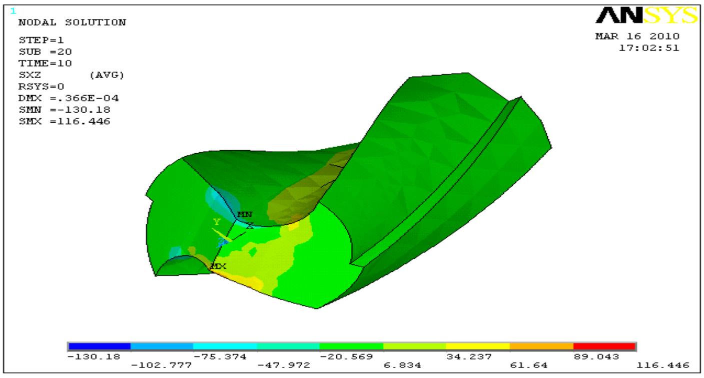

Fig. 8: shear stress distribution in xz direction at an angle of 116^0

III. RESULTS AND DISCUSSION

In this chapter comparison of drill bits with two helix angles (114^0, 116^0) are geared up by comparing their von mises stresses, shear stress and deflection [4].

Table 2: Consolidate results of two different helix angles

Micro drills	**Vonmises StressN/mm^2**	**Deflection (mm)**	**Shear Sress in XY Plane**	**Shear Sress in YZ Plane**	**Shear Sress in XZ Plane**
Drill 1(114^0)	305.987	0.409E-04	97.126	66.684	37.708
Drill 2(116^0)	346.88	0.366E-04	40.222	70.751	116.446

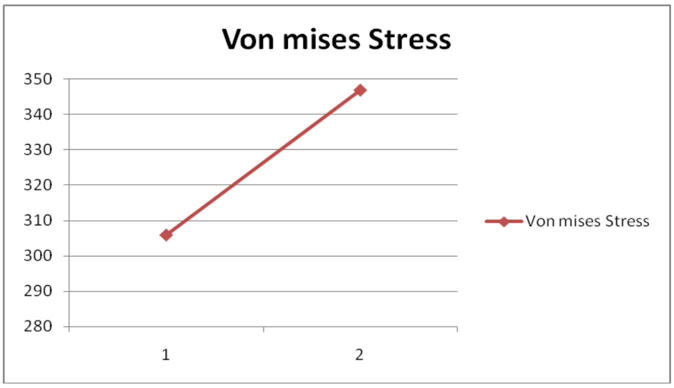

Fig. 9: Graph showing the von mises stress of two different helix angles

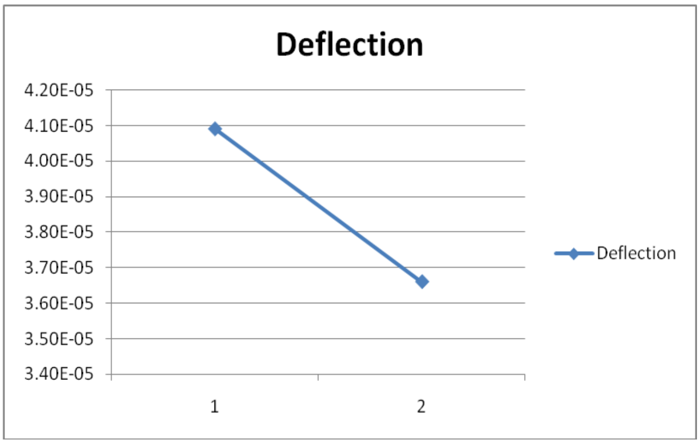

Fig. 10: Graph showing the deflection of two different helix angles

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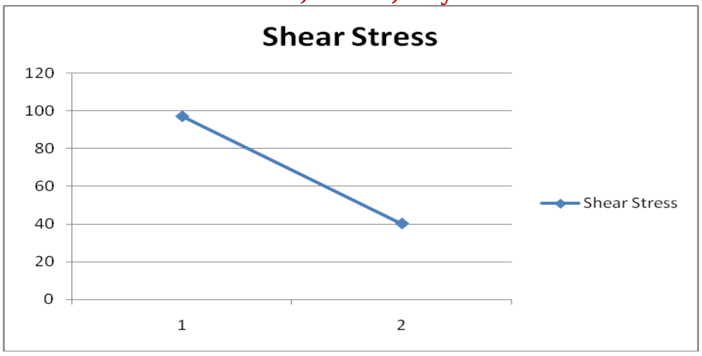

Fig. 11: Graph showing the shear stress distribution of two different helix angles.

By comparing the above results as shown in Fig. 9 to 11 and table 2, the minimum deformation and shear stress distribution is at helix angle 116^0.

IV. CONCLUSION

By examining the Analysis result, it is clear that the drill with the lower stresses experience a longer life before breakage. From the obtained result it is clear that the micro drill with point angle 116^0 is having less stress distribution. The drill with the lower stresses when loaded with the internal drilling forces is micro drill with point angle 114^0 which is shown through analysis to have longer life when compare to other model. Moreover the best suited geometry for micro drill is with point angle 116^0 and the life cycle is increased from 105 to 106 cycles when compared to 114^0 so the best suited geometry for micro drill is with point angle 116^0.

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