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STUDY & ANALYSIS OF MICRO NEEDLE MATERIAL BY ANSYS

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ABSTRACT

In this research the concept of design and analysis, silicon and stainless steel based on hollow micro-needles for transdermal drug delivery(TDD) have been evaluated by Using ANSYS & computational fluid dynamic (CFD), structural. Micro fluidic analysis has performed to ensure the micro-needles design suitability for Drug delivery. The effect of axial and transverse load on single and micro-needle array has investigated with the mechanical properties of micro-needle. The analysis predicted that the resultant stresses due to applied bending and axial loads were in the desired range. In computational fluid dynamic (CFD) static analysis, the fluid flow rate through micro-needle array has investigated by applying the pressure the inlet to ensure that the micro-needles were capable for flow of drug up to the desired range. Towards achieving painless injections and other micro fluidic applications, the main aim to focus on the conically tapered hollow needles of micron dimensions. The relationship between pressure drop and flow rate through micro-needles was experimentally quantified as a function of fluid viscosity, micro-needle length, diameter, and cone half-angle. The dimensionless pressure drop sharply decreased as increased the indicating role of viscous forces on the boundaries of the micro-needles. The flow was in viscid, indicates that the effect of pressure drop, numerical simulations shows that the flow through conically tapered micro-needles was mainly controlled by the diameter with taper angle of the micro-needle tip. In this research the hollow out-of-plane micro-needle of micron sized devices for drug delivery applications were obtained.

KEYWORDS: Micro-needles, transdermal drug delivery (TDD), computational fluid dynamic (CFD), conically tapered micro-needles.

INTRODUCTION

Transdermal drug delivery is becoming increasingly popular because it is not associated with the potential risks and pain of traditional hypodermic needles. One method for transdermal drug delivery uses adhesive skin patches. A micro structured transdermal system also called micro-needles consists of an array of micro structured projections coated is applied to the skin to provide intradermal delivery of active agents, which otherwise would not cross the stratum corundum. The mechanism based on diffusion as it is in other transdermal drug delivery products. It is based on the temporary mechanical disruption of the skin and the placement of the drug. It can more readily reach its site of action. Micro-needles are commonly fabricated using metals, silicon and stainless steel other materials. the techniques employed for their fabrication are usually quite complex and expensive. Metallic micro-needles are typically fabricated by electroplating technique. To achieve micro-needle-based drug delivery is preferably made with arrays of needles over a certain area. Drug delivery remains one of the most important challenges in medicine and micro fabrication is used to develop novel delivery systems. In last year's, new miniaturized delivery systems based on both solid and hollow micro-needles have been proposed for the controlled release of small doses of drugs throughout the outermost layer of the skin we present a simple silicon hollow out-of-plane micro-needle for drug delivery. Transdermal drug delivery is an appealing alternative that offers good patient compliance and the possibility of control release over time while avoiding possible degradation due to the gastrointestinal tract or first-pass liver effects use aqueous coating solution to prevent denaturing of proteins and other biological molecules. Micro-needles are significantly smaller than ordinary needles, especially concerning the length. In recent years, attention has been drawn to a new type of delivery method where arrays of miniaturized needles are used to penetrate the skin layer. Since the needles are short, they do not reach the nerve-rich regions of the lower parts of the skin. As a consequence, the stimulus caused by micro-needle insertion into the skin is weak and perceived as painless. By combining micro-needles with a patch like structure, a system can be realized which essentially has all the favourable properties of a traditional transdermal patch. Continuous release, ease-

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of-use, unobtrusiveness and painlessness. Advances in the processing of materials on a micro-scale have led to the development and introduction of devices that employ very small needles that have significant potential in devices for diagnostics, healthcare monitoring and drug delivery by mechanically perforating the outer skin layer and allowing for transdermal drug absorption or fluid sampling. These processing techniques incorporate one or more technologies that enable the precise machining, extrusion, casting, and/or forming of from one to an array or grid of micro-needles. Since the needles are short, they do not reach the nerve-rich regions of the lower 3 parts of the skin. As a consequence, the stimulus caused by micro-needle insertion into the skin is weak and perceived as painless. However, if a small number of needles are used, the delivery rate per needle needs to be higher than in the case of many needles. It is shown that solid micro-needles can increase skin permeability by almost four orders of magnitude. Whereas Single hollow silicon hypodermic micro-needles with fully enclosed fluid channels fabricated through a combination of surface and bulk micro machining techniques where a silicon nitride shell is built on top of a silicon substrate. The efficiency of transdermal drug delivery has been shown to imp rove by increasing the number of micro-needles. In last year's, new miniaturized delivery systems based on both solid and hollow micro-needles have been proposed for the controlled release of small doses of drugs, the insertion force of the needles does not necessarily need to be minimized. This is basically true. However, if a small number of needles are used, the delivery rate per needle needs to be higher than in the case of many needles.

MATERIAL SELECTION

Silicon:

Silicon was the material selected for the first MNs used for drug delivery because the technology needed to manufacture micron or submicron structures only became available with the advent of industrial high-precision microelectronics tool. Silicon has proved very useful in manufacture of microstructures and micro electro mechanical systems for a number of reasons. Its main advantage is that there is much flexibility in the processes that can be used to shape, meaning that microstructures in a variety of desirable shapes and sizes can be readily produced. Using mono crystalline or polycrystalline silicon allows tailoring of specific solutions to a broad range of requirements. Moreover, silicon offers many attractive physical properties, making it an attractive and versatile material

MATERIALS AND METHODOLOGY

Characterization of micro-needle geometry:

Micro-needles were imaged by scanning electron microscopy to determine their base radius, tip radius, and wall thickness. Interfacial area (the effective area of contact between the needle and the skin) was then calculated in two ways.

(i) The annular surface area, A a at the needle tip

$$A\ a = \pi\ (rt – t^2/4) \qquad (1)$$

The, full cross-sectional area, A f at the needle tip

$$A\ f = \pi rt^2 \qquad (2)$$

Needle wall angle, α, was calculated as

$$A = \tan^{-1}\{(r\ b – r\ t)/h\} \qquad (3)$$

Where rt is the outer radius of the micro-needle tip, rb is the outer radius at the needle base, t is the wall thickness, and 'h' is the height.

THEORETICAL ANALYSIS

Mechanical Design of Micro-needle:

In this, the designs of conical tapered hollow-out-of plane micro-needles are designed. 'L' represents the length of micro-needles is 500 µ m. The inlet diameter (Di) of micro-needle is 110 µm and outlet diameter (Do) of micro-needle is 60 µ m. Pi and Po represents the inlet and outlet pressures. Q presents the flow rate. The centre-to-centre distance of the micro-needle in array is 1000 µm. The fluid reservoir is designed on the backside of the micro-needle.

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Micro-needle Mechanics:

The micro-needles experience resistive forces by skin when inserted into skin. Therefore, in order to penetrate the micro-needle into the skin, the applied axial force on micro-needle should be greater than the skin resistive forces. An axial force acts on the micro-needle tip during insertion. This axial force is compressive and causes buckling of the micro-needle. Failure of micro-needle is possible during skin insertion due to bending or buckling. The axial force can be reduced by decreasing the tip area of the micro-needle. As buckling is directly related with compressive force, which acts during insertion, sharp micro-needle tip reduces buckling. Hence insertion of micro-needle into the skin becomes easy. The bending may also occur due to uneven surface of skin or human error. Hence, the design of micro-needle is important for proper delivery without any failure. The axial force (compressive force) which the micro-needle can withstand without breaking is given by (1).

$$F\ Compressive = \sigma\ y\ A \qquad (1)$$

Where 'σ y' is yield strength, and 'A' is cross sectional area of the micro-needle tip which is very small. The cross sectional area of hollow cylindrical section is

$$A = \pi /8(Do^4 - Di^4)$$

.

Where, Do is the outer diameter and Di is the inner diameter of the hollow cylindrical section of micro needles. The yield strength of Silicon is 7 G Pa.

$$F\ Buckling = \pi^2 EI/L^2 \qquad (2)$$

Where, E is young's modulus, I is moment of inertia, and L is length of the micro-needle. Moment of inertia for the hollow cylindrical section is

$$I = A = \pi/64(Do^4+Di^4).$$

Needle always penetrate into the skin with particular angle. There is a risk involve in micro-needle fracture during skin puncturing. The bending force at which the micro-needle can withstand without breaking is given by (3).

$$F\ Bending = \sigma\ y\ I\ /c\ L \qquad (3)$$

Where, c = D/2 is the distance from vertical axis to the outer edge of the section.

MICRO FLUIDIC ANALYSIS

The design of micro needle is conically tapered, so Ponselle's law is considered to measure the fluid flow through micro needle array during micro fluidic analysis and given as.

$$Q1 = \pi\ Di^4\ V\ P/64\mu L \qquad (4)$$

Where, Q1 is the flow rate, Di is the inner diameter of micro needle and μ is the viscosity. Modified Bernoulli equation is considered to model the geometry of micro needles. The pressure loss is calculated by considering the friction losses and given by:

$$P_1/pg+V_1//\mathbf{2}g+Z_1 = P^2/pg+V^2/2g+Z^2 + fl/d+V^2/2g+\Sigma\ KV^2/2g \qquad (5)$$

Where, P_1 is inlet pressure, P_2 is outlet pressure, V_1 is inlet velocity, V_2 is outlet velocity and f is friction factor. Since the cylindrical section is symmetrical about a vertical axis, the outlet pressure, velocity and the distances (Z_1 and Z_2) remain the same. The friction factor for laminar flow is given as

$$f = 64/Re$$

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NUMERICAL SIMULATION

Using ANSYS, two different types of simulations have been conducted before the fabrication of micro needles to envisage the suitability of micro-needles design for drug delivery. Single micro needle was modeled in structural analysis to investigate the mechanical properties of micro- needle. In micro fluidic analysis the fluid flow rate was investigated through 5*5 micro-needle array. Finite element method (FEM) has been used in these analysis.

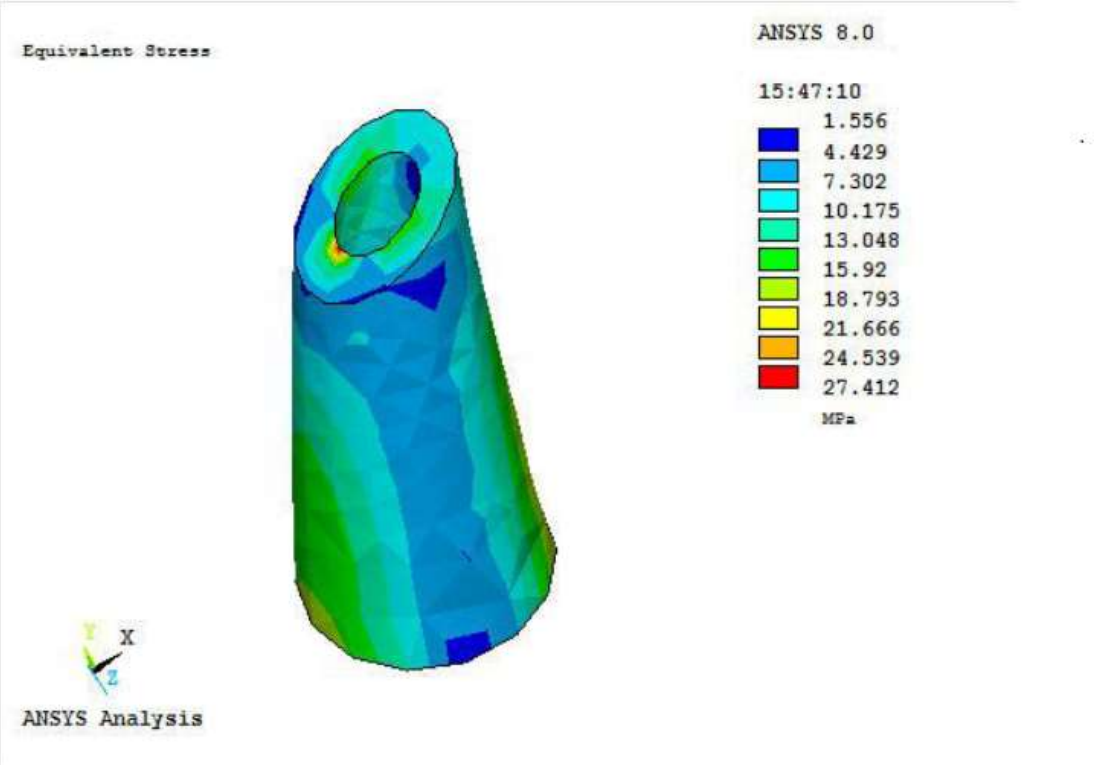

Fig. Bending Stress Analysis

Velocity v/s pressure graph

Velocity(m/s)	Pressure drop (k Pa)
10	60
20	240
30	550
40	975
50	1500
60	2200
67	2750

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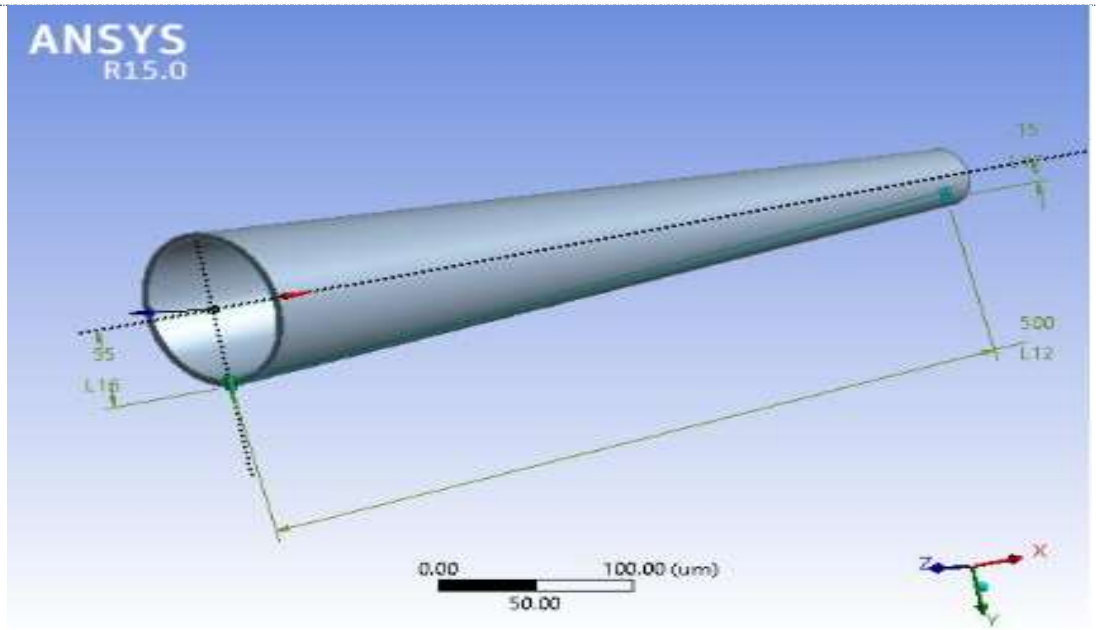

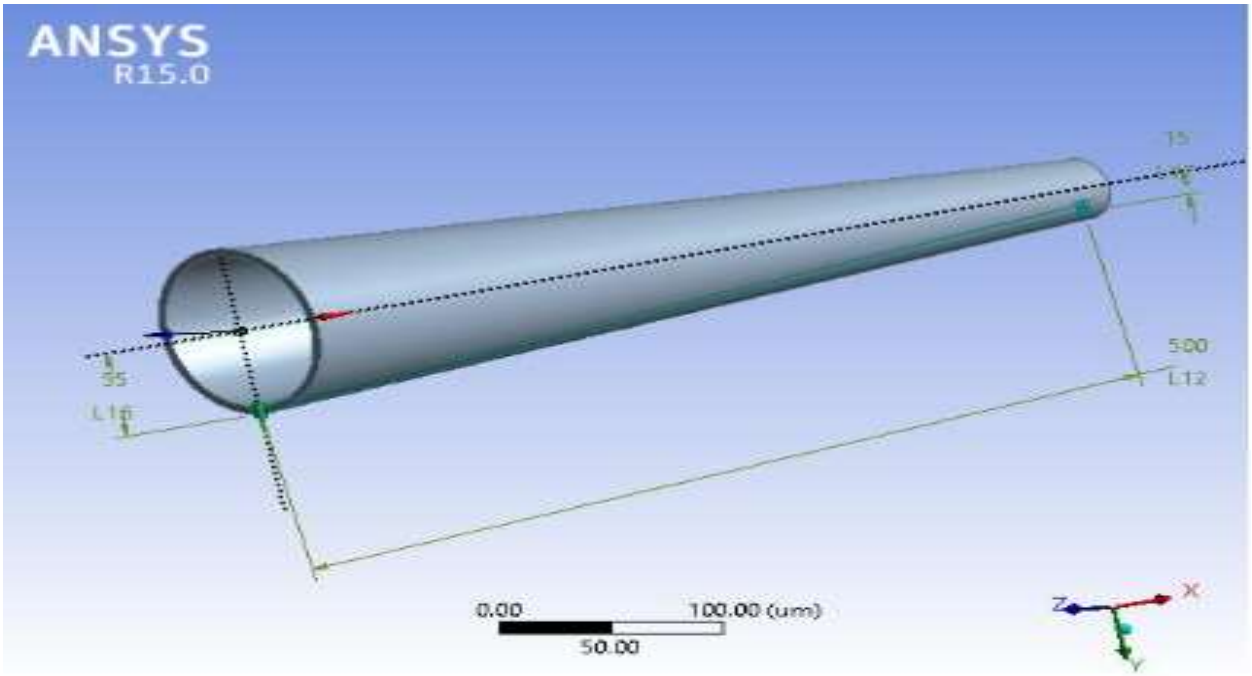

Force V/S total deformation

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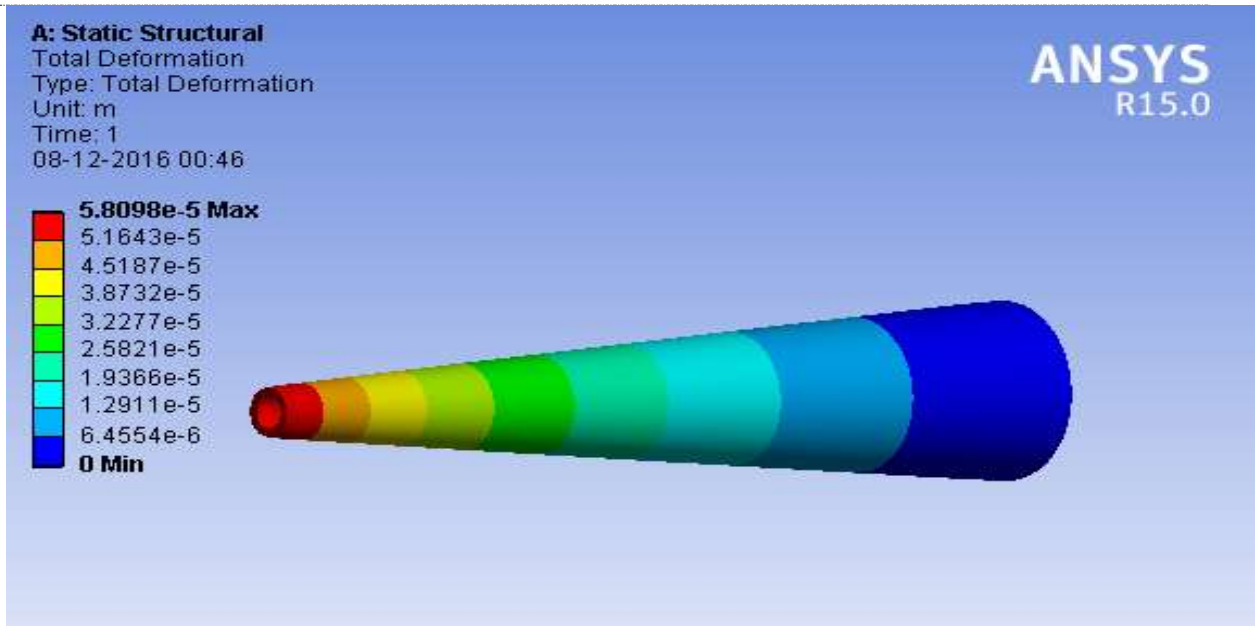
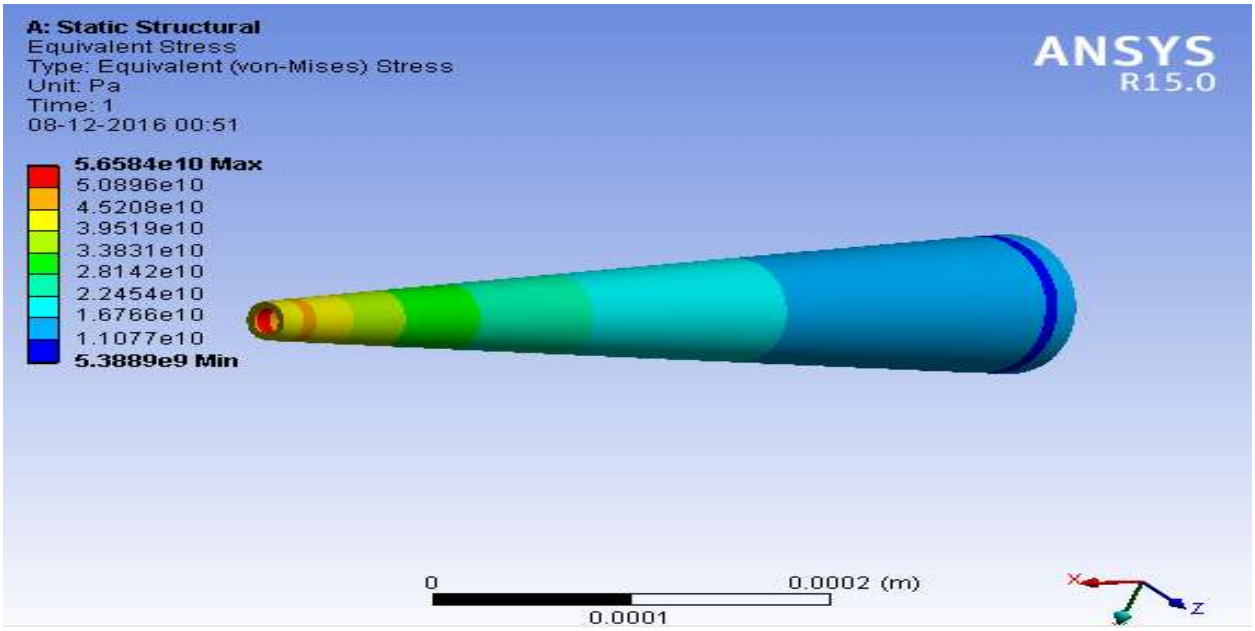


Force V/S Equivalent stress



Meshing of modele

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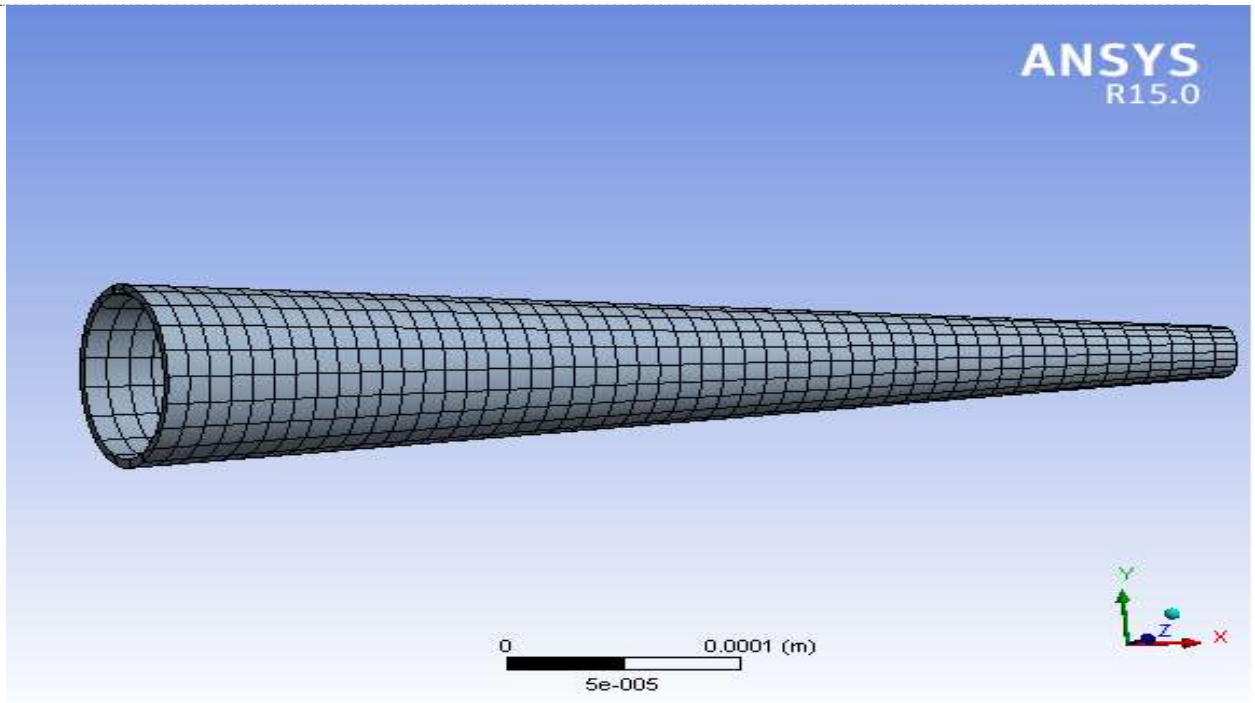
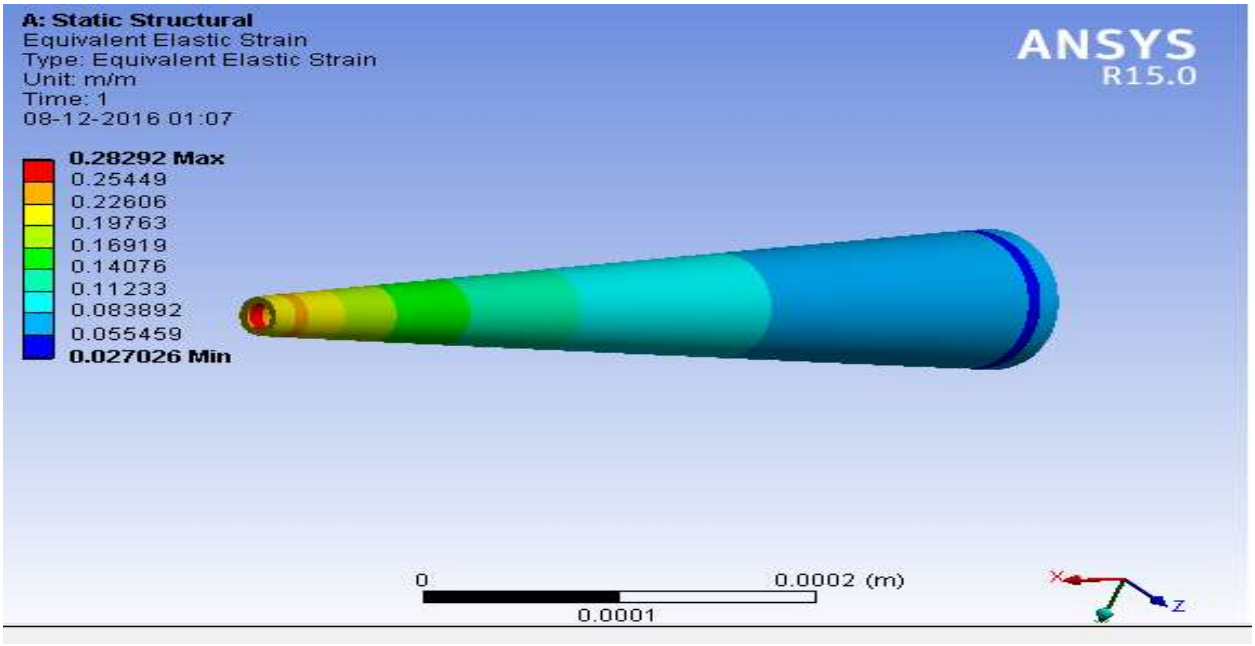


Force V/S Equivalent Elastice strain



RESULT

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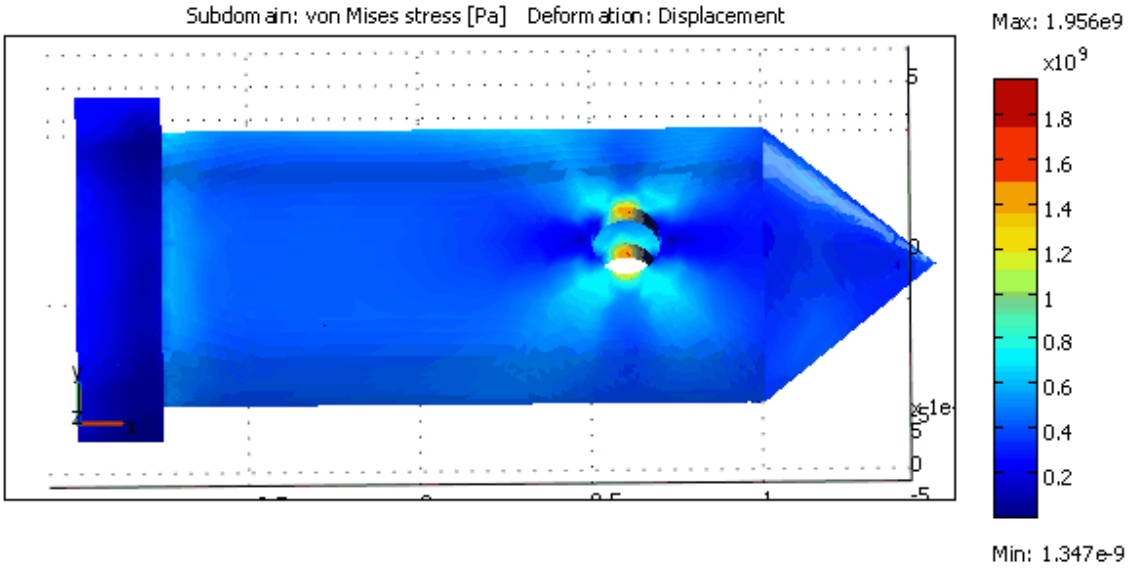

Boundary condition:
The bases of the Micro-needles are attached to some other device. So the base surfaces are fixed with respect to the rest of the micro-needle.

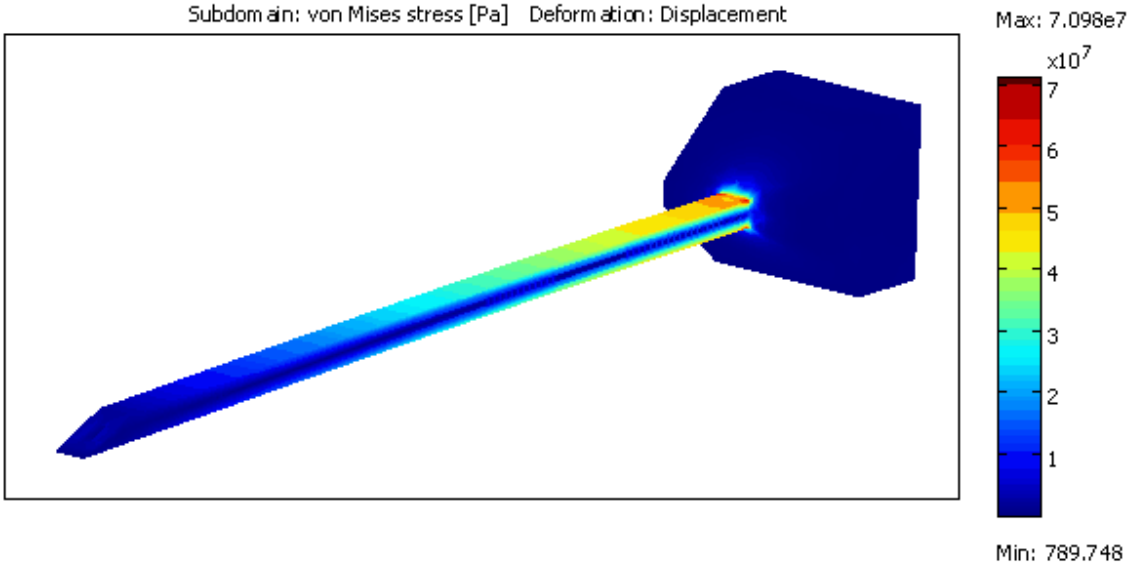

Figure 4 (a) and (b): Region of maximum stress in the out-of-plane and

Study of simulation:

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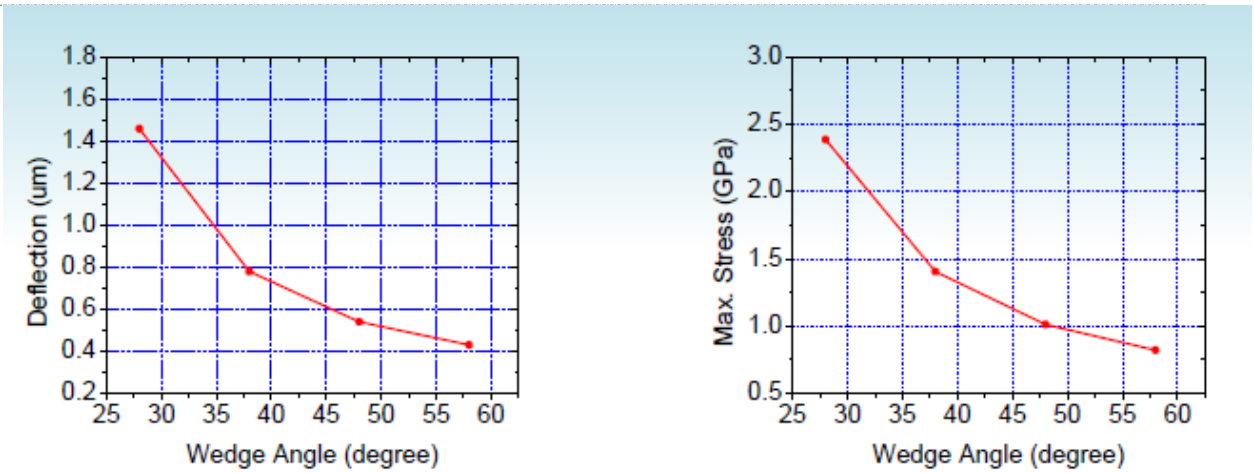

Fig- Variation of deflection and maximum stress with tip angle for Out-of plane needle

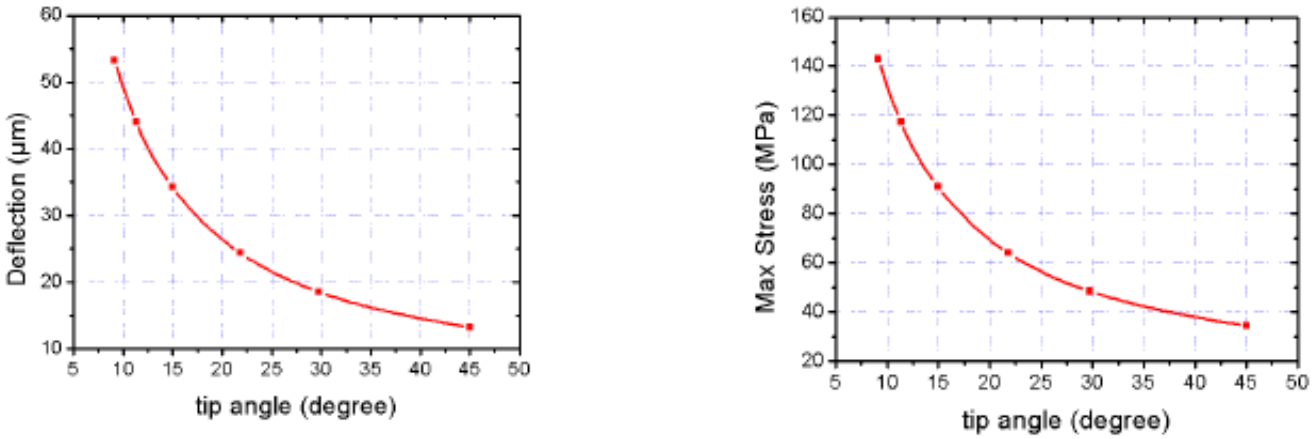

Fig- Variation of deflaction and maximum stress In-plane needle

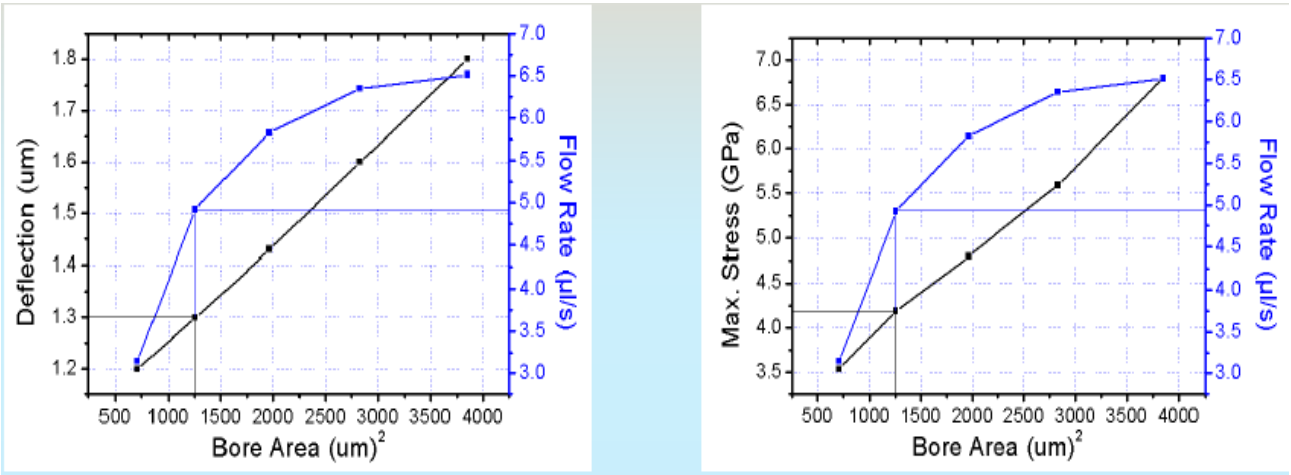

Fig-Variation of deflaction maximum stress and flow rate with needle bore area for out-of-plane needle

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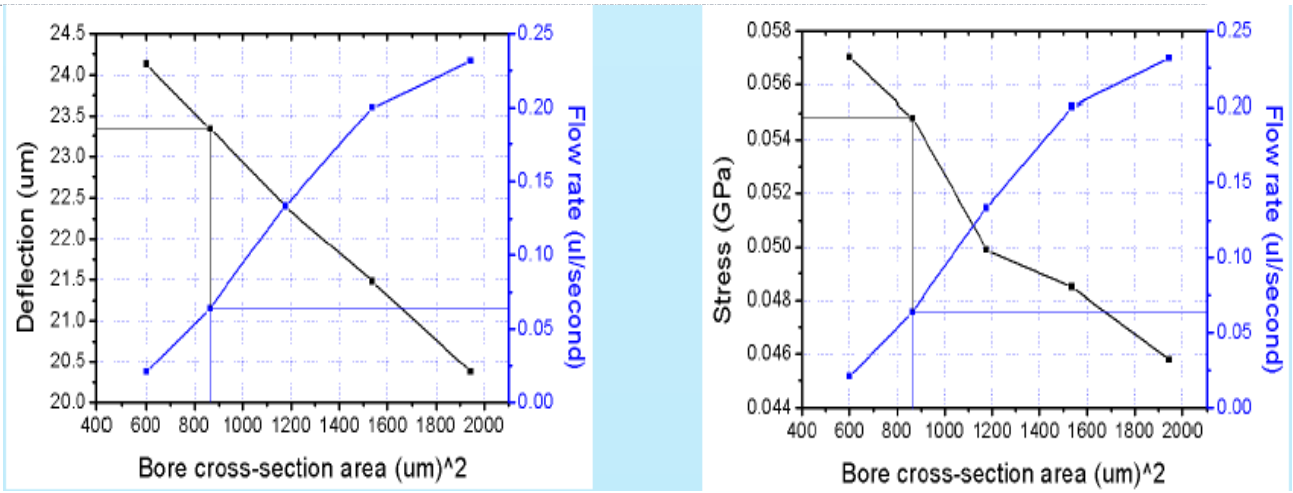

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Fig- Variation of deflection maximum stress and flow rate with needle Bore area for in-plane needle

CONCLUSION

In this paper, silicon based hollow micro needles and array for using characterization, mechanical design, numerical simulation and micro needle mechanics. this research carried out by using theoretical approach to study the fluid flow discharge rate, time and modelled on the ANSYS 14.0 platform, the mathematical equations which provide the values considered while fabrication of micro-needle. For use contents unit, geometry(solid),coordinate relevance (100), and statically structure force reaction ,load form stress, strain and nodal force as for as linear buckling static structural and total deformation (4.105 e).we got finally result density(2330),specific heat(702kg^{-1}c^{-1}),thermal conductivity (124wm^{1}c^{-1})all data take after ANSYS analysis silicon based micro needle.

THIS WORK CAN BE EXTENDING

Complete structural analysis of design which includes Bending stress, Buckling stress and Axial.

[1] Micro fluidic behaviour of the fluid which has to flow through it. Pressure v/s velocity and discharge behaviour.
[2] Future, the following In developments are possible
[3] Fabrication and testing of the micro-needle.5
[4] Simulation and fabrication of the 2 dimensional array of micro needle.
[5] Development of dimensional arrays by combining multiple 2 dimension arrays
[6] Design and coupled multi physics simulation of a two chamber electrostatic Micro-pump.
[7] Exploration of fabrication processes and testing of the fabricated micr- Pump.

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