A CFD and Heat Flux Analysis of Various PLASMA Arc Cutting Nozzles by using ANSYS

Mr. Dattu B. Ghane

Lecturer in Mechanical Engineering, Government Polytechnic Awasari (Khurd), Pune, Maharashtra, India

---***---

Abstract- *Recently various types and different sizes of plasma arc cutting nozzles are used for the different types of metal cutting. Mainly plasma arc cutting nozzle sizes are 1/16, 3/64, 1/32 and 5/64 considered for the analysis. From the experimentation and analysis done before on these nozzles operating parameters of the plasma arc cutting machine and nozzle design parameters are taken in consideration as prime affecting factors. That experimentation and analysis was includes dimensional analysis, roughness parameters and amount of material removed of cutting materials as operating parameters for optimization for machine. Also includes effect on design parameters as nozzle shell diameter, nozzle length after burning and nozzle inner shell center pin diameter after burning to find out the minimum wear nozzle size i.e. 3/64. However this paper gives the results on a CFD and heat flux analysis of these plasma arc cutting nozzles with different sizes i.e. 1/16, 3/64, 1/32 and 5/64 by using ANSYS software. Nozzle meshed models with brick and triangular 981 elements and 3024 nodes are used for the analysis considering the uniformly distributed maximum load as 5000 N. During analysis the maximum and minimum limit is found out by this analysis for these nozzles as safe operating zone with respect to stress and strain produced while metal cutting.*

Key Words: ANSYS software, CNC Plasma, CFD, heat flux analysis, nozzle wears etc.

1. INTRODUCTION

The basic plasma arc cutting process produces superheated electrical flame by electrically ionizing gas called plasma. Work piece cutting is required flame torch in plasma arc cutting method. Plasma arc cutting machine used for cutting is also required with optimized input operating parameters like cutting speed, oxygen pressure, LPG pressure, air gap etc. Operating parameters of the plasma arc cutting machine should produce minimum width variation at different section of the work piece[1]. However cutting speed is taken 700 mm/min, 0.2 bar acetylene pressure, 1.5 bar oxygen pressure, 1.5 bar propane pressure and air gap 1.1 mm for experimentation on 10 mm thick metal plate and found optimized[2]. Torch flame is achieved by propellant (i.e. oxygen, air, inert gas and others depending on material being cut) and is passed out through a pin hole of nozzle with high velocity on the metal work piece for cutting. This causes the wear of nozzle affecting the design parameters of nozzle like nozzle shell diameter, nozzle length and nozzle inner shell center pin diameter after burning for cutting the metals. Experimentation is done on 1/16, 3/64, 1/32 and 5/64 these types of nozzles and after wear analysis found that the 3/64 type nozzle is the best for all results including minimum wear rate[2]. The heat generated while cutting operation leading to increase the temperature of nozzle resulting to unbalance in the stresses and strains generated within nozzle body material. Hence this approach of CFD and heat flux analysis by using ANSYS software is efficient and found out the maximum and minimum limits of stress and strains for safe operating zone for plasma arc cutting nozzles.

2. METHODOLOGY

The analysis is done on the 1/16, 3/64, 1/32 and 5/64 these four types of nozzles used for plasma arc cutting machine to cut the metal samples carried further from my previous experimentation and analysis work[1] [2]. The CATIA software is used to produce the 3D model, whereas CAD software is used for generating the 2D drawings of these nozzles. The material selected as MS for all nozzles is EN47 having other properties as tensile strength 210 GPA, yield strength 1158 MPA, young's modulus 1034 MPA, poisson ratio 0.266 and density 7700 kg/mm^3. The further analysis is done by importing the 3D geometries of nozzles in ANSYS software. Applied temperature is varied as per the specifications at 5000 N load and heat flux values are generated in terms of stress and strain after processing as a result.

3. STEADY STATE ANALYSIS OF NOZZLES

3.1 Steady State Analysis of Nozzle Size: 1/16

Figure 3.1.1 shows the imported geometry of Nozzle and has been created in CATIA software. The 3D model of Nozzle total length is 83.7 mm. Figure 3.1.2 shows the imported geometry of Nozzle and has been created in CAD software. The 2D model of Nozzle total length is 83.7mm. Figure 3.1.3 shows the meshed model of Nozzle with brick and triangular elements are used, this analysis having an element 981 and node 3024. Meshing is nothing but the discretization of object into the small parts called as the element. Previous Studies show that the best results are obtained using brick and triangular mesh. Considering the concept of grid independent it is been found that this is the best suited size of mesh hence this size of mesh has been selected. Figure 3.1.4 shows the convectional model of Nozzle. Fixed support has restriction to move in X and Y direction as well as rotation about that particular point. For the Nozzle 1/16 analysis bottom point the Nozzle the ground so this frame cannot move in any of the directions i.e. all the degrees of freedom are blocked. Since the load is uniformly distributed on the Nozzle 1/16, here in this study uniformly distributed load 5000 N (Max.) The uniformly distributed load is shown in fig 3.3.4 which is 20% more of the unlading weight material and upper body.

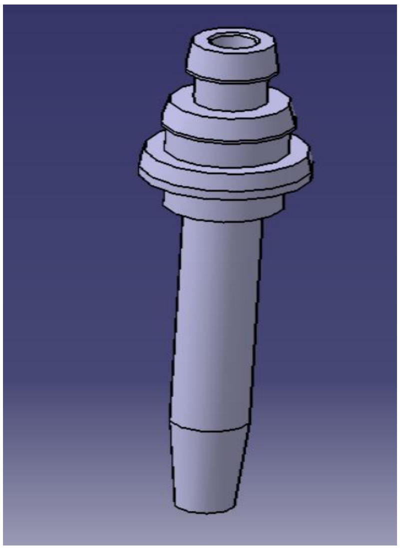

Figure: 3.1.1 – Imported geometry of Nozzle 1/16 from CATIA.

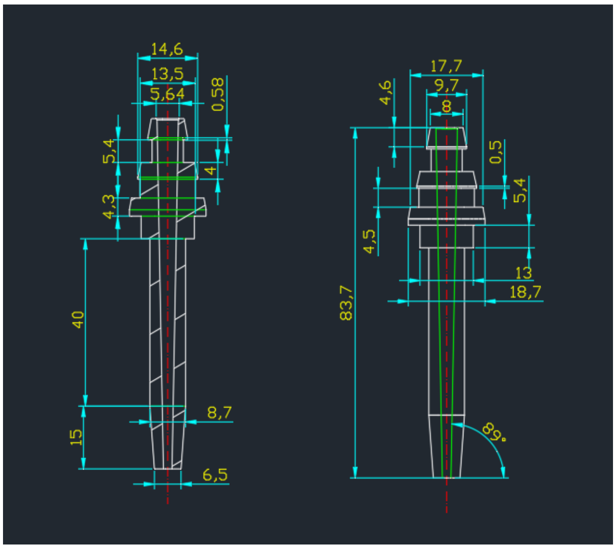

Figure: 3.1.2 – Imported geometry of Nozzle 1/16 from CAD.

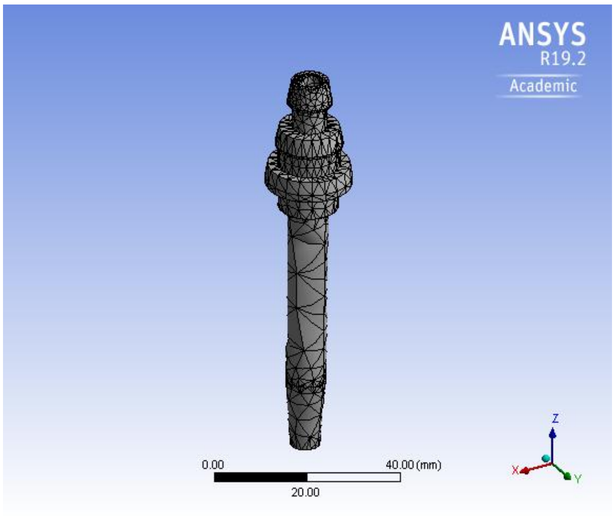

Figure: 3.1.3 – Meshed model of Nozzle 1/16.

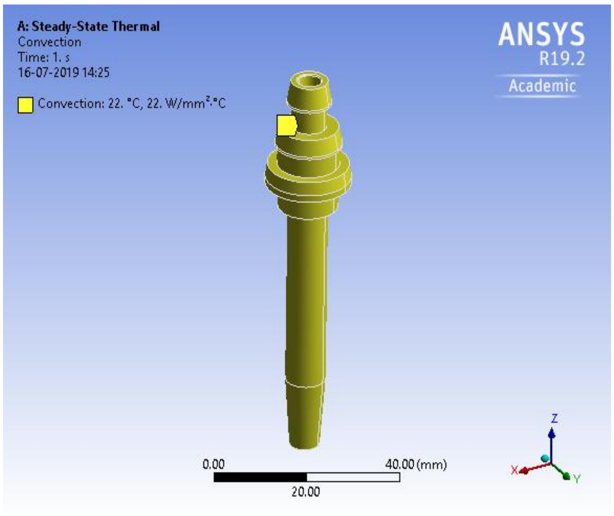

Figure: 3.1.4 – Convectional Model of Nozzle 1/16.

Figure 3.1.5 shows the temperature model of Nozzle. Fixed support has restriction to move in X and Y direction as well as rotation about that particular point. For the Nozzle 1/16 analysis bottom point the Nozzle the ground so this frame cannot move in any of the directions i.e. all the degrees of freedom are blocked. Since the load is uniformly distributed on the Nozzle 1/16, here in this study uniformly distributed load5000 N (Max.) The uniformly distributed load is shown in fig 3.1.5 which is 20% more of the unlading weight material and upper body. Figure 3.1.6 shows the Temperature of Nozzle under the application of 1460 ^{0}C temp. The maximum Temperature is at the Nozzle and its maximum with Red zone indicates the area of maximum deflection and blue zone indicates the area of minimum deflection, which is shown by colour band. Figure 3.1.7 shows the equivalent Heat Flux induced in Nozzle under the action of 1460 ^{0}C temp. Red zone indicates the area of maximum stress and blue zone indicates the area of minimum temp. Figure 4.1.8 shows the equivalent Heat Flux induced in Nozzle under the action of 1460 ^{0}C temp. Red zone indicates the area of maximum strain and blue zone indicates the area of minimum strain

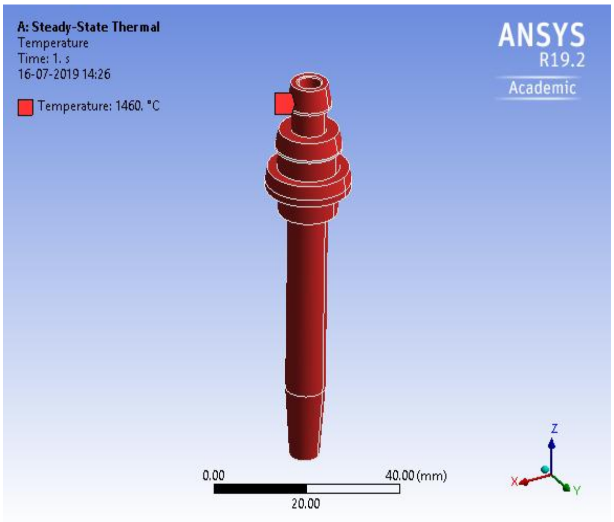

Figure: 3.1.5 – Temperature Model of Nozzle 1/16.

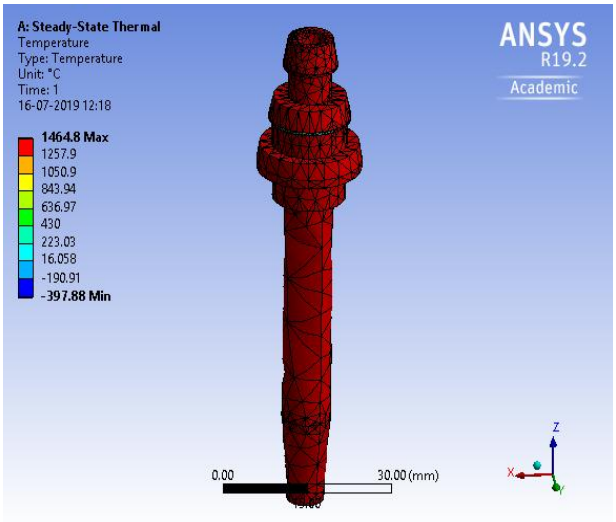

Figure: 3.1.6 – Total Temperature of Nozzle 1/16.

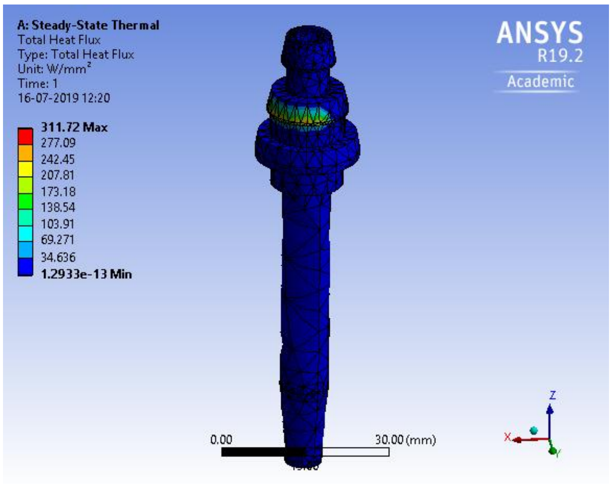

Figure: 3.1.7 – Total Heat Flux of Nozzle 1/16.

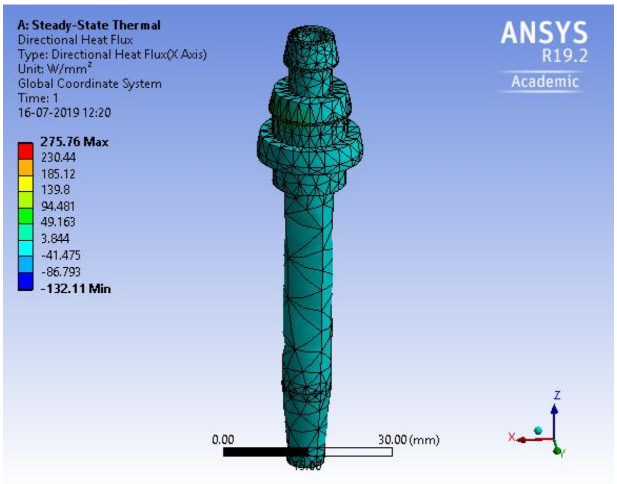

Figure: 3.1.8 – Directional Heat Flux of Nozzle 1/16.

3.2 Steady State Analysis of Nozzle Size: 3/64

Figure 3.2.1 shows the imported geometry of Nozzle and has been created in CATIA software. The 3D model of Nozzle total length is 88.7 mm. Figure 3.2.2 shows the imported geometry of Nozzle and has been created in CAD software. The 2D model of Nozzle total length is 88.7 mm. Figure 3.2.3 shows the meshed model of Nozzle with brick and triangular elements are used, this analysis having an element 981 and node 3024. Meshing is nothing but the discretization of object into the small parts called as the element. Previous Studies show that the best results are obtained using brick and triangular mesh. Considering the concept of grid independent it is been found that this is the best suited size of mesh hence this size of mesh has been selected. Figure 3.2.4 shows the conventional model of Nozzle. Fixed support has restriction to move in X and Y direction as well as rotation about that particular point. For the Nozzle 1/16 analysis bottom point the Nozzle the ground so this frame cannot move in any of the directions i.e. all the degrees of freedom are blocked. Since the load is uniformly distributed on the Nozzle 1/16, here in this study uniformly distributed load 5000 N (Max.) The uniformly distributed load is shown in fig 3.2.4 which is 20% more of the unlading weight material and upper body.

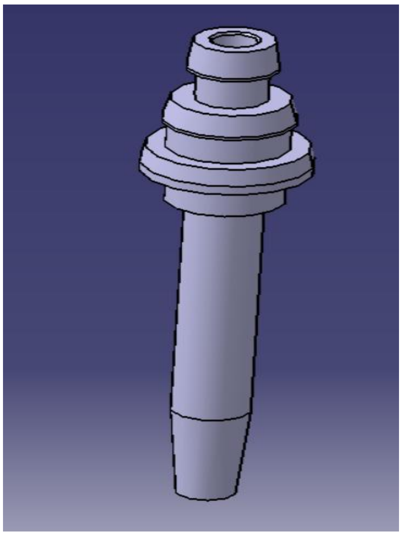

Figure: 3.2.1 – Imported geometry of Nozzle 3/64 from CATIA.

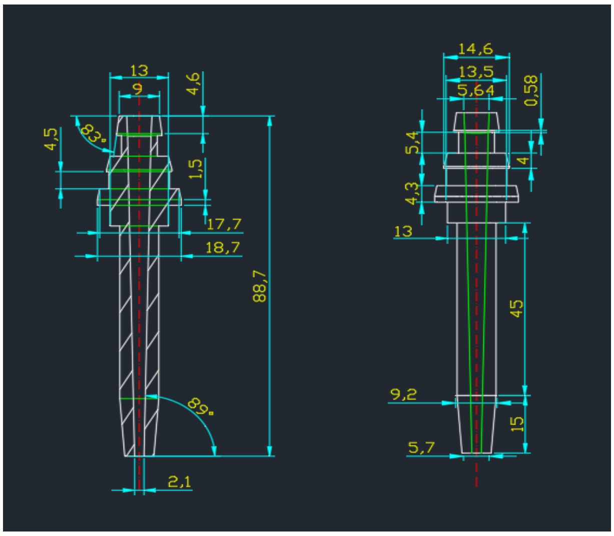

Figure: 3.2.2 – Imported geometry of Nozzle 3/64 from CAD.

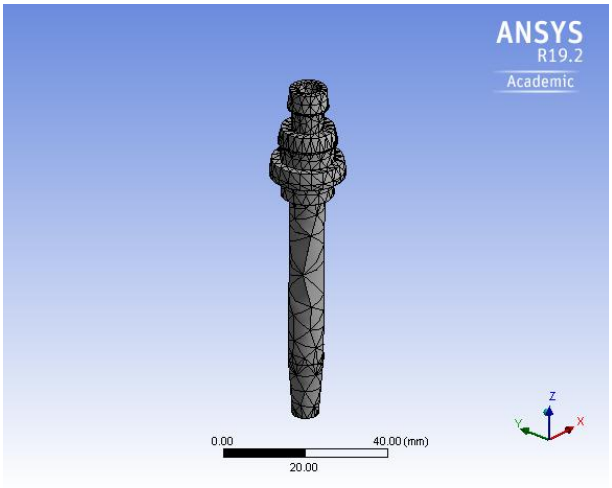

Figure: 3.2.3 – Meshed model of Nozzle 3/64.

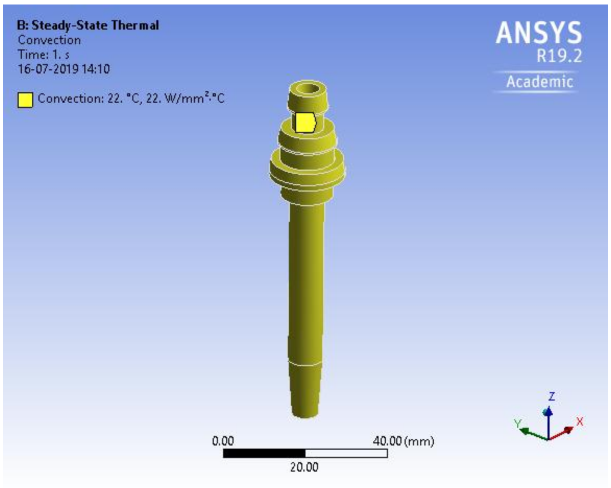

Figure: 3.2.4 – Conventional Model of Nozzle 3/64.

Figure 3.2.5 shows the temperature model of Nozzle. Fixed support has restriction to move in X and Y direction as well as rotation about that particular point. For the Nozzle 1/16 analysis bottom point the Nozzle the ground so this frame cannot move in any of the directions i.e. all the degrees of freedom are blocked. Since the load is uniformly distributed on the Nozzle 1/16, here in this study uniformly distributed load5000 N (Max.) The uniformly distributed load is shown in fig 3.2.5 which is 20% more of the unlading weight material and upper body. Figure 3.2.6 shows the Temperature of Nozzle under the application of 1180 ^{0}C temp. The maximum Temperature is at the Nozzle and its maximum with Red zone indicates the area of maximum deflection and blue zone indicates the area of minimum deflection, which is shown by colour band. Figure 3.2.7 shows the equivalent Heat Flux induced in Nozzle under the action of 1460 ^{0}C temp. Red zone indicates the area of maximum stress and blue zone indicates the area of minimum temp. Figure 3.2.8 shows the equivalent Heat Flux induced in Nozzle under the action of 1460 ^{0}C temp. Red zone indicates the area of maximum strain and blue zone indicates the area of minimum strain

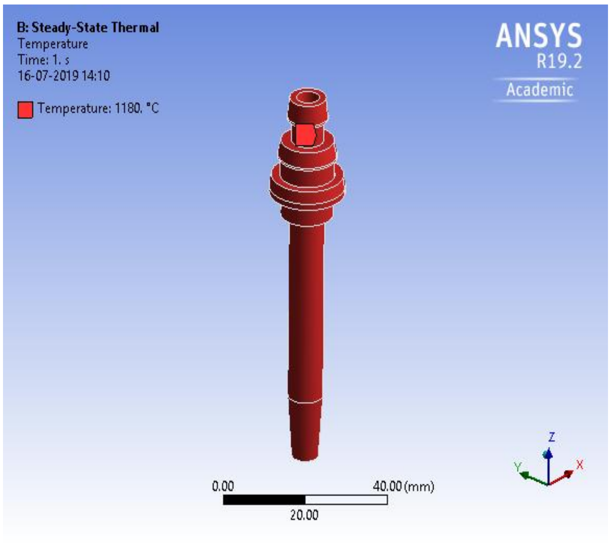

Figure: 3.2.5 – Temperature Model of Nozzle 3/64.

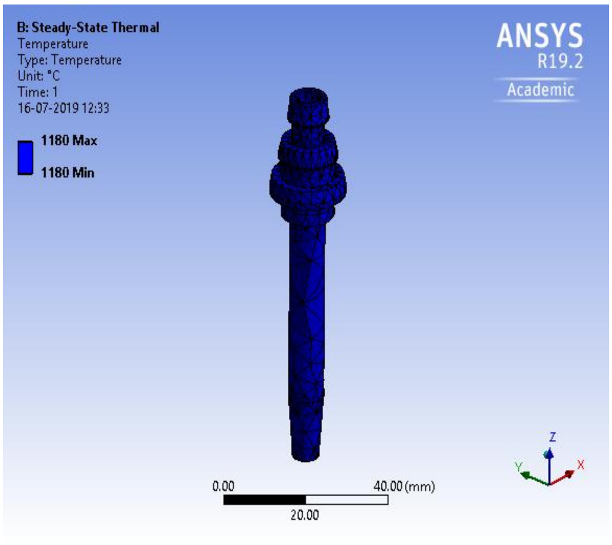

Figure: 3.2.6 – Total Temperature of Nozzle 3/64.

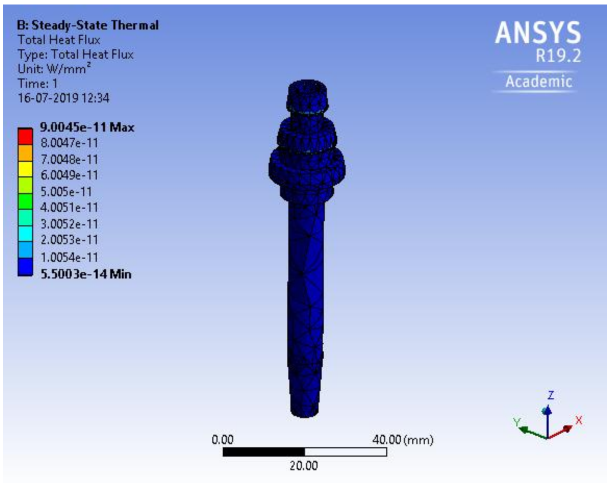

Figure: 3.2.7 – Total Heat Flux of Nozzle 3/64.

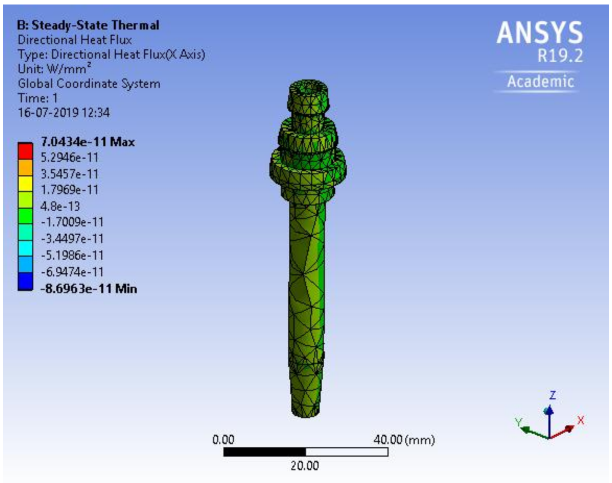

Figure: 3.2.8 – Directional Heat Flux of Nozzle 3/64.

3.3 Steady State Analysis of Nozzle Size: 1/32

Figure 3.3.1 shows the imported geometry of Nozzle and has been created in CATIA software. The 3D model of Nozzle total length is 88.7 mm. Figure 3.3.2 shows the imported geometry of Nozzle and has been created in CAD software. The 2D model of Nozzle total length is 88.7 mm. Figure 3.3.3 shows the meshed model of Nozzle with brick and triangular elements are used, this analysis having an element 981 and node 3024. Meshing is nothing but the discretization of object into the small parts called as the element. Previous Studies show that the best results are obtained using brick and triangular mesh. Considering the concept of grid independent it is been found that this is the best suited size of mesh hence this size of mesh has been selected. Figure 3.3.4 shows the conventional model of Nozzle. Fixed support has restriction to move in X and Y direction as well as rotation about that particular point. For the Nozzle 1/16 analysis bottom point the Nozzle the ground so this frame cannot move in any of the directions i.e. all the degrees of freedom are blocked. Since the load is uniformly distributed on the Nozzle 1/16, here in this study uniformly distributed load 5000 N (Max.) The uniformly distributed load is shown in fig 3.3.4 which is 20% more of the unlading weight material and upper body.

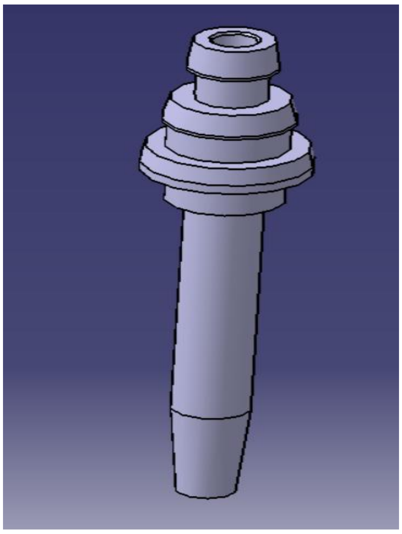

Figure: 3.3.1 – Imported geometry of Nozzle 1/32 from CATIA.

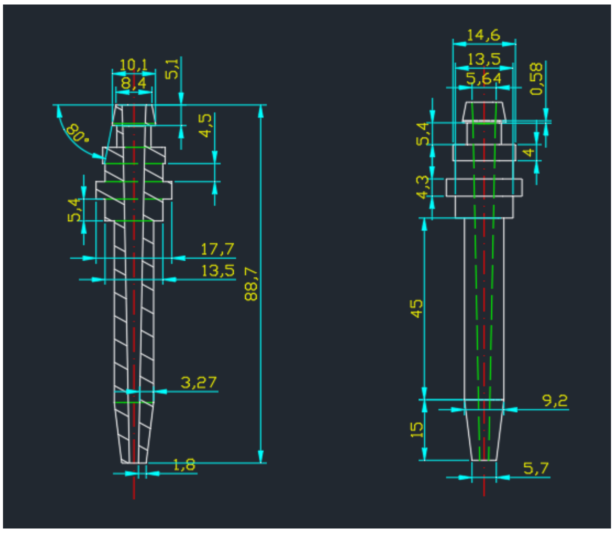

Figure: 3.3.2 – Imported geometry of Nozzle 1/32 from CAD.

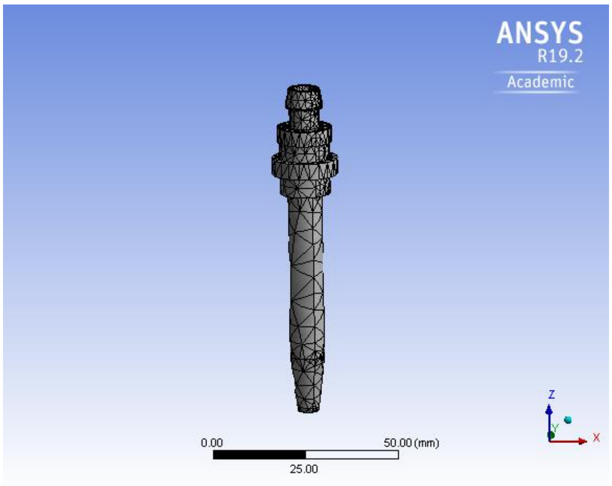

Figure: 3.3.3 – Meshed model of Nozzle 1/32.

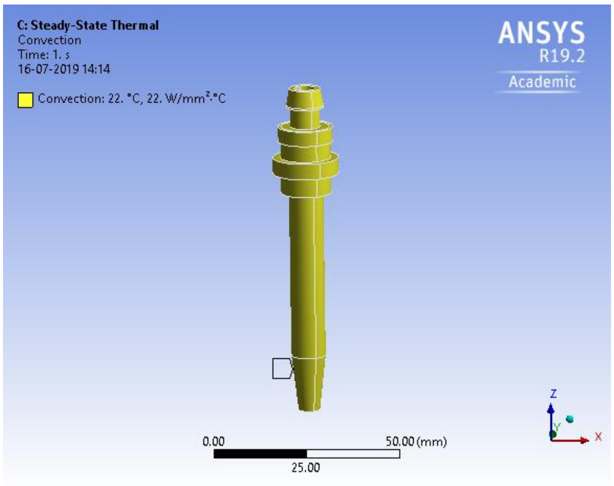

Figure: 3.3.4 – Conventional Model of Nozzle 1/32.

Figure 3.3.5 shows the temperature model of Nozzle. Fixed support has restriction to move in X and Y direction as well as rotation about that particular point. For the Nozzle 1/16 analysis bottom point the Nozzle the ground so this frame cannot move in any of the directions i.e. all the degrees of freedom are blocked. Since the load is uniformly distributed on the Nozzle 1/16, here in this study uniformly distributed load5000 N (Max.) The uniformly distributed load is shown in fig 3.3.5 which is 20% more of the unlading weight material and upper body. Figure 3.3.6 shows the Temperature of Nozzle under the application of 1600 ^{0}C temp. The maximum Temperature is at the Nozzle and its maximum with Red zone indicates the area of maximum deflection and blue zone indicates the area of minimum deflection, which is shown by colour band. Figure 3.3.7 shows the equivalent Heat Flux induced in Nozzle under the action of 1460 ^{0}C temp. Red zone indicates the area of maximum stress and blue zone indicates the area of minimum temp. Figure 3.3.8 shows the equivalent Heat Flux induced in Nozzle under the action of 1460 ^{0}C temp. Red zone indicates the area of maximum strain and blue zone indicates the area of minimum strain

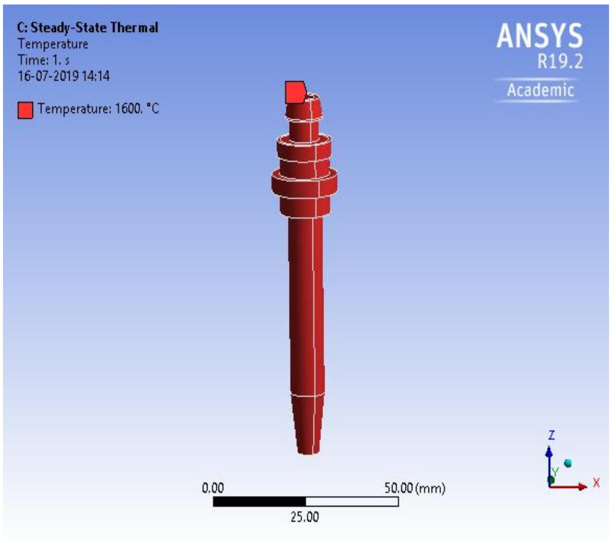

Figure: 3.3.5 – Temperature Model of Nozzle 1/32.

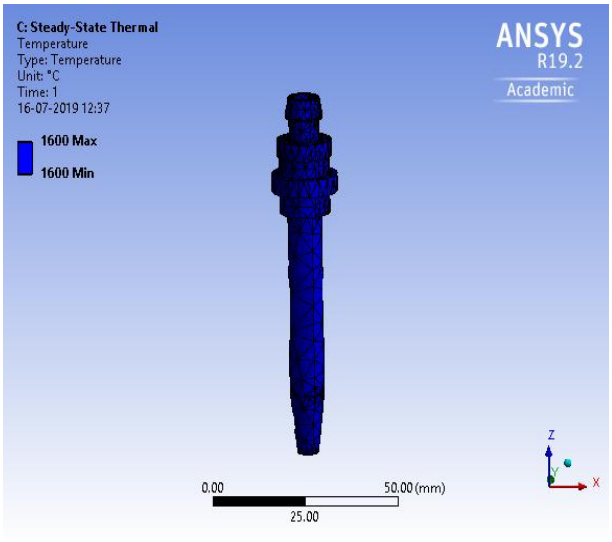

Figure: 3.3.6 – Total Temperature of Nozzle 1/32.

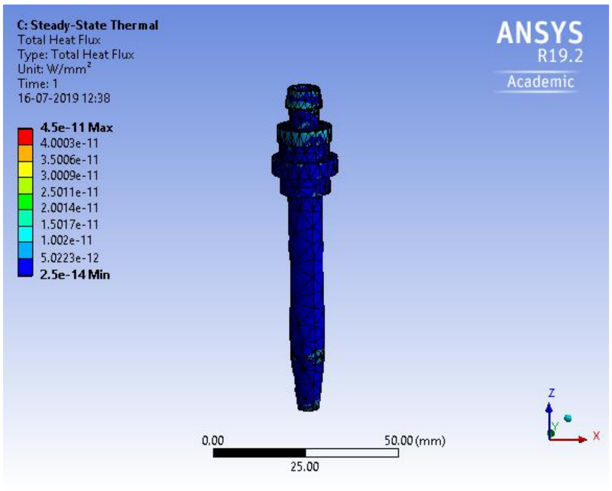

Figure: 3.3.7 – Total Heat Flux of Nozzle 1/32.

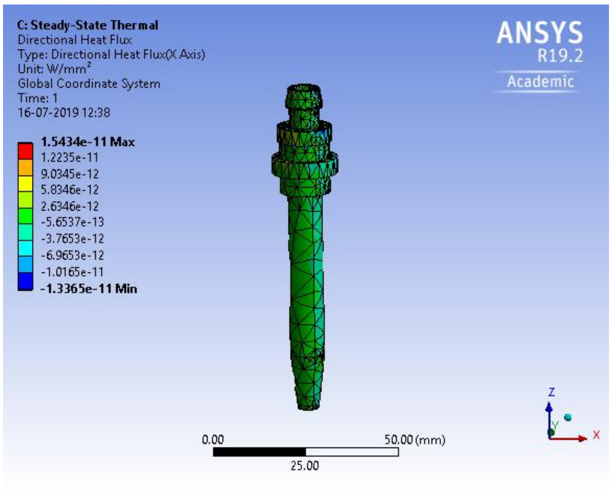

Figure: 3.3.8 – Directional Heat Flux of Nozzle 1/32.

3.4 Steady State Analysis of Nozzle Size: 5/64

Figure 3.4.1 shows the imported geometry of Nozzle and has been created in CATIA software. The 3D model of Nozzle total length is 81.7 mm. Figure 3.4.2 shows the imported geometry of Nozzle and has been created in CAD software. The 2D model of Nozzle total length is 81.7 mm. Figure 3.4.3 shows the meshed model of Nozzle with brick and triangular elements are used, this analysis having an element 981 and node 3024. Meshing is nothing but the discretization of object into the small parts called as the element. Previous Studies show that the best results are obtained using brick and triangular mesh. Considering the concept of grid independent it is been found that this is the best suited size of mesh hence this size of mesh has been selected. Figure 3.4.4 shows the conventional model of Nozzle. Fixed support has restriction to move in X and Y direction as well as rotation about that particular point. For the Nozzle 5/64 analysis bottom point the Nozzle the ground so this frame cannot move in any of the directions i.e. all the degrees of freedom are blocked. Since the load is uniformly distributed on the Nozzle 5/64, here in this study uniformly distributed load 5000 N (Max.) The uniformly distributed load is shown in fig 3.4.4 which is 20% more of the unlading weight material and upper body.

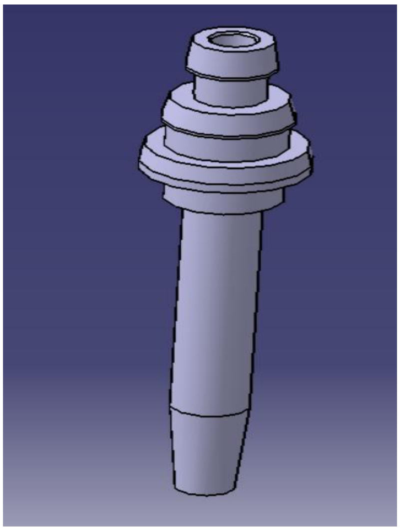

Figure: 3.4.1 – Imported geometry of Nozzle 5/64 from CATIA.

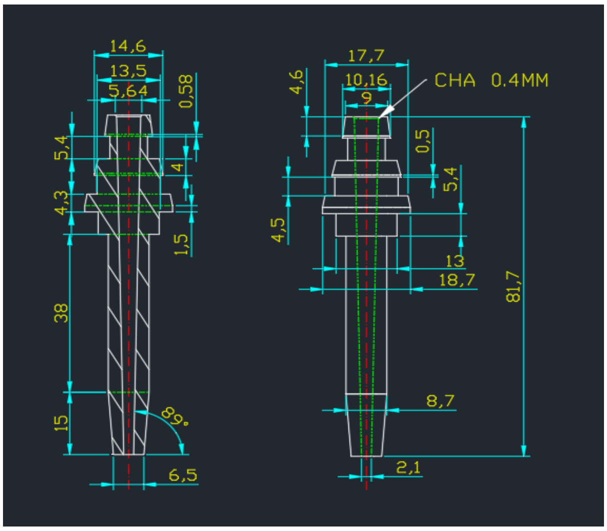

Figure: 3.4.2 – Imported geometry of Nozzle 5/64 from CAD.

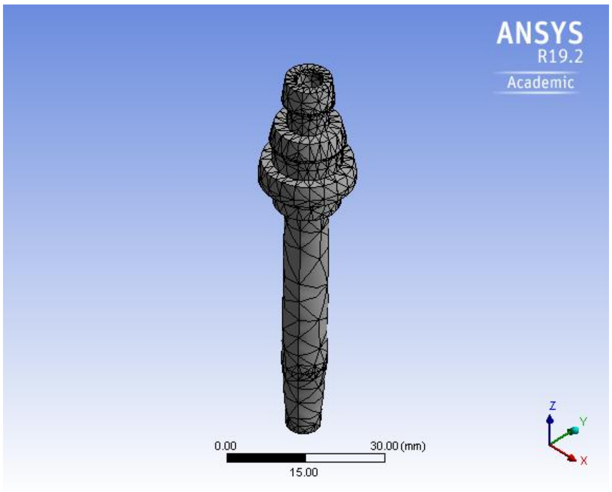

Figure: 3.4.3 – Meshed model of Nozzle 5/64.

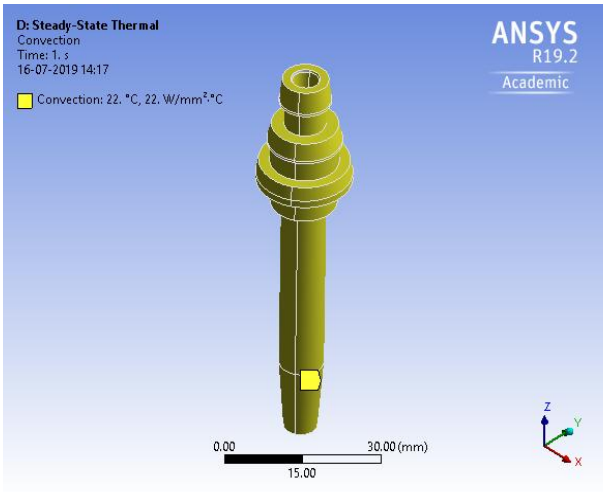

Figure: 3.4.4 – Conventional Model of Nozzle 5/64.

Figure 3.4.5 shows the temperature model of Nozzle. Fixed support has restriction to move in X and Y direction as well as rotation about that particular point. For the Nozzle 5/64 analysis bottom point the Nozzle the ground so this frame cannot move in any of the directions i.e. all the degrees of freedom are blocked. Since the load is uniformly distributed on the Nozzle 5/64, here in this study uniformly distributed load5000 N (Max.) The uniformly distributed load is shown in fig 3.4.5 which is 20% more of the unlading weight material and upper body. Figure 3.4.6 shows the Temperature of Nozzle under the application of 1650 ^{0}C temp. The maximum Temperature is at the Nozzle and its maximum with Red zone indicates the area of maximum deflection and blue zone indicates the area of minimum deflection, which is shown by colour band. Figure 3.4.7 shows the equivalent Heat Flux induced in Nozzle under the action of 1460 ^{0}C temp. Red zone indicates the area of maximum stress and blue zone indicates the area of minimum temp. Figure 3.4.8 shows the equivalent Heat Flux induced in Nozzle under the action of 1460 ^{0}C temp. Red zone indicates the area of maximum strain and blue zone indicates the area of minimum strain

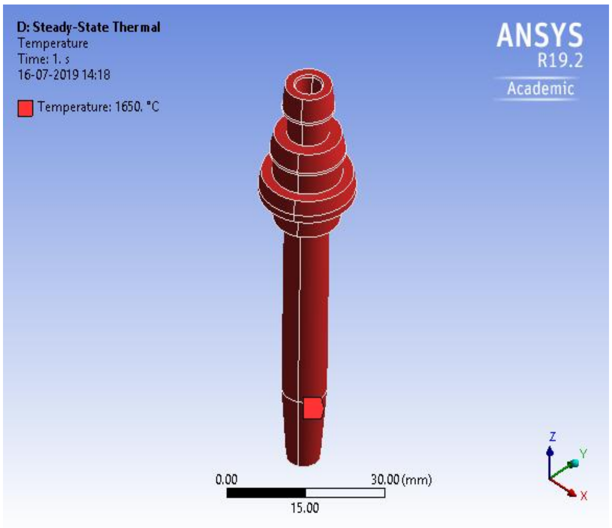

Figure: 3.4.5 – Temperature Model of Nozzle 5/64.

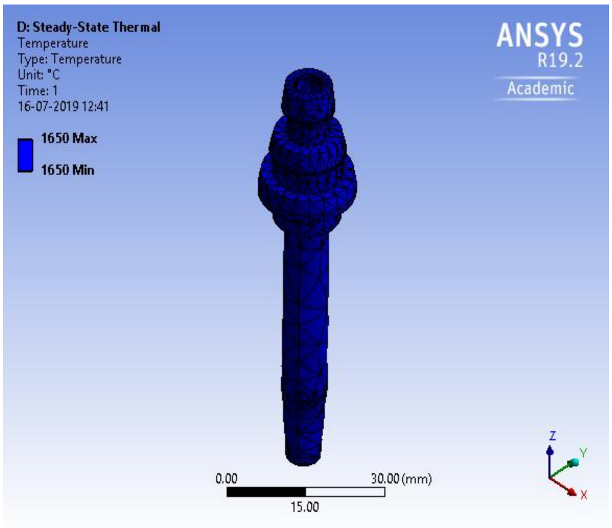

Figure: 3.4.6 – Total Temperature of Nozzle 5/64.

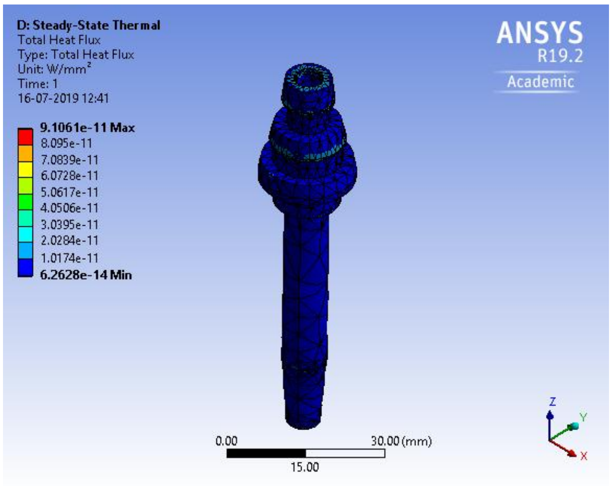

Figure: 3.4.7 – Total Heat Flux of Nozzle 5/64.

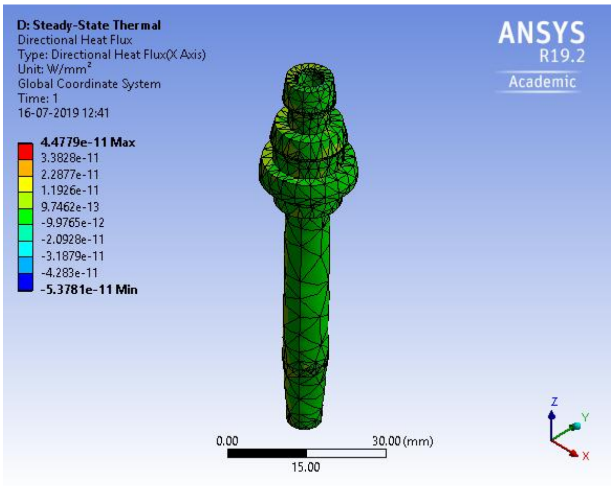

Figure: 3.4.8 – Directional Heat Flux of Nozzle 5/64.

4. RESULTS AND DISCUSSION

Figure 4.1 shows the applied temperature, Figure 4.2 shows total heat flux, Figure 4.3 shows heat flux for stress analysis and Figure 4.4 shows heat flux for strain analysis on nozzles as 1/16, 3/64, 1/32 and 5/64 by using ANSYS software. Hence maximum and minimum limit is found out the operating safe zone by this analysis for these nozzles with respect to stress and strain produced while metal cutting.

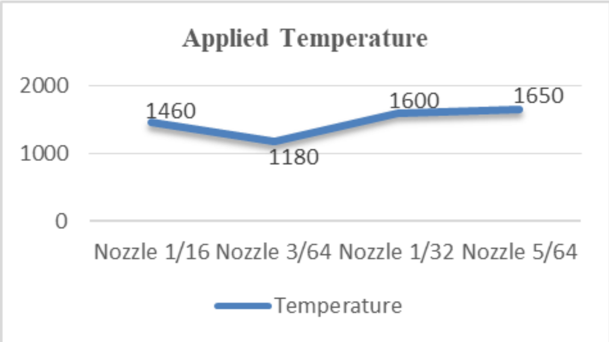

Figure: 4.1 – Temperature analysis of the Nozzles.

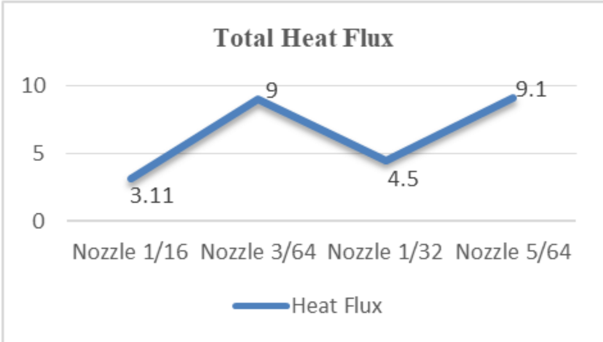

Figure: 4.2 – Total heat flux analysis of the Nozzles.

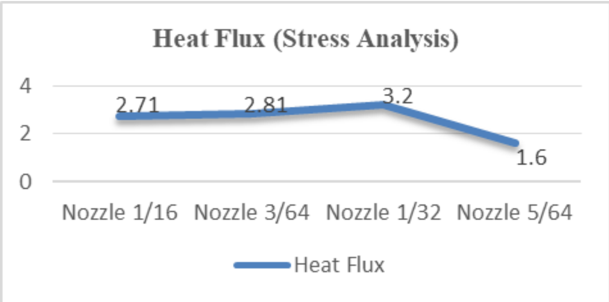

Figure: 4.3 – Heat heat flux analysis of Nozzles.

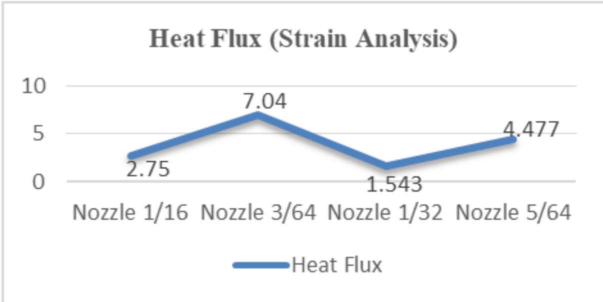

Figure: 4.4 – Directional heat flux analysis of Nozzles.

REFERENCES

[1] Dattu Balu Ghane, L. B. Abhang, P. A. Makasare, B. N. Kharad, (November 2018-January 2019). Optimization on operating parameters of CNC plasma machine by experimentation, i-manager's Journal on Instrumentation & Control Engineering (JIC), Volume 7. No. 1, ISSN : 2321-113X.

[2] Mr. Dattu B. Ghane, (Dec 2019). Optimization of Design Parameters and Nozzle wear on CNC plasma machine by experimentation, International Research Journal of Engineering and Technology (IRJET), Volume: 06, Issue: 12, e-ISSN: 2395-0056, p-ISSN: 2395-0072.

ABOUT THE AUTHORS

Mr. Dattu Balu Ghane is working as a Lecturer in the Department of Mechanical Engineering at Government Polytechnic, Awasari, Pune, Maharashtra, India. He is having wide industrial experience at world leading research center. He holds a Bachelor and Master degrees in Mechanical Engineering. He has published a large number of research articles in National and International Journals of high repute. His academic life includes serving as an AMIE Project Guide, Subject Expert and conducting a number of training programs. His areas of interest are Automotive Technology Design, Pollution Control, Energy Conservation and Human Resource Development, Supply Chain Management, Simulation, Lean Manufacturing and Solar Energy. He has been awarded with various states, national and international awards.