

STUDY THE NATURAL CONVECTION OF HEAT TRANSFER OF STRUCTURAL STEEL CYLINDER BY USING ANSYS TRANSIENT THERMAL

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ABSTRACT

Structural steel has become one of the most widespread building materials from last hundred year. It is broadly used in critical infrastructure such as buildings, cylinders, and marine pipelines, etc. In this paper, natural convection heat transfer is used for cooling steel cylinders by using ANSYS Transient Thermal. A cylinder is designed to have a radius of 10 mm and a depth of 40 mm. The initial temperature of the cylinder is 120°C and the ambient temperature is 22°C. When we apply a convection coefficient of 1×10^{-5} W/mm²°C, the steel cylinder starts to cool down with the passage of time. The temperature decreases from 120°C to 22.357°C in the 10000s. These results show that the heat transfer (cooling rate) is rapid at the start of simulation but gradually decreases with the increase in time. When we apply the final convection coefficient of 2.2×10^{-5} W/mm²°C, the temperature decreases from 120°C to 22.755°C in 3800s. These simulations show that the cooling rate has directly related to the Convection heat coefficient.

Keywords: Structural Steel, Convection heat transfer, Convection heat coefficient, ANSYS



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Introduction:

Structural Steel has become one of the most widespread building materials from last hundred year. It is one of most usual constructional material which is extensively used in all aspect of modern-day construction. It has become one of the most widespread building materials from last hundred year. In soaring buildings, the dominance of structural steel is manifest and possesses substantial social and economic benefits [1, 2]. It is broadly used for critical infrastructures as ships, , marine pipelines, aircraft hangers, commercial and residential buildings, bridges, solid cylinders, warehouses, metro stations, , storage tanks, Harbor and offshores structure, etc. [3].



Fig. 1: Harbor facilities made by structural steel [4]

In several instances, rate of heat transfer is significant. Cooling of systems has great application in modern technology. They are extensively used in Automobiles and industrial equipment. The most efficient method of cooling includes: Cooling by water spray, mist cooling and forced convection by air jet cooling and applying high air pressure. In various parts, the convection heat transfer plays a significant role in transferring of heat. Natural convection has enough advantages as a tool of heat transfer. Natural convection uses the flow of fluid such as air on the surface of the material to transfer the heat from system to surrounding [5-8]. Convection heat transfer depend on three factors as temperature difference, area, convection coefficient [9].

The most significant parameter for the convection process is convection heat coefficient. It is truly dependent upon the wind velocity and other surface characteristics. The smooth surfaces have less convection coefficient as compared to rough surfaces under the constant velocity of wind. The faster velocities of wind correspond to the greater convection coefficient. This greater convection coefficient leads more heat transfer which cause a more rapid decrease in the temperatures of the bodies [10]. In this paper, we studied the behavior of cooling structural steel cylinder by using natural convection heat transfer. In many fields, a usual issue is natural convection of horizontal cylinder. Hundreds of researches have been initiated and completed to know the reasons of heat transfer in the air through horizontal cylinder [5].

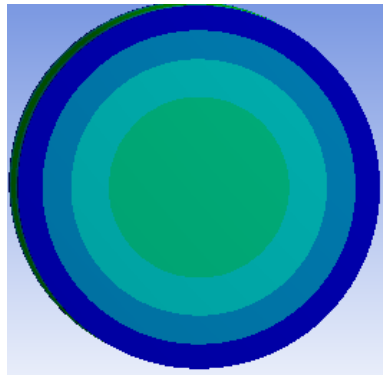


Fig. 2

Due to such importance of convection heat transfer, many researches and experiments are done in this field of convection heat transfer and Thermal Convection change in heat transfer in solid cylinder. In 1971, R.L Riley et al. studied about the air mixing, convection and Ultraviolet (UV) air disinfection in rooms [11]. In 1979, A.B Cohen analyzed the thickness of fin for improve of natural convection array of rectangular fins [12]. In 1983, A.B Cohen et al. analyzed the natural convection of thermally optimum arrays of fins and cards [13]. In 1991, H. Barthels et al. studied the experimental and theoretical investigation under the natural convection conditions for the safety behavior of small helium gas-cooled high temperatures reactors (HTRs) [14]. In 2000, K. Nakajima et al. examined about the moist convection of Jupiter's atmosphere by using 2-D fluid dynamical model with clarify cloud micro-physics of the water [15]. In 2002, Y. Bai et al. studied the systematic changes in apple rings in the course of convection air-drying along with controlled humidity and temperature [16]. In 2003, M. Iyengar et al. analyzed the coefficient of performance (COPT) in forced convection for plate fin heat sinks [17]. In 2008, N. Hatami et al. studied the natural convection heat transfer coefficient in a vertical flat-plate solar air heater [18]. In 2014, H.H. Al-Kayiem et al. predicted the convection heat transfer coefficient between flowing air and surfaces on the rectangular passage solar air heater [19]. In 2019, Y.G Lee et al. did tests on vertical tube of passive containment cooling system to study air-steam condensation under natural convection [20]. In 2019, A. Moradikazerouni et al. examined the computer's central processing unit (CPU) heat sink through stratified coerced convection by using structural stability method [21]. In 2020, M.H Alturaihi et al. studied heat transfer in square cavity filled with saturated porous media and fluid to look over thermal conductivity and void ratio [22]. Different researchers use ANSYS and Fuzzy simulation for different researches and get very useful results [23-38]

Simulation

ANSYS is an extremely impressive and innovatory software for multi-physics simulations. It is normally the most valuable and widespread software design which is utilized to illustrate the collaboration of comprehensive controls of pulsation, warm exchange alongside electromagnetic alteration, fluid, simple and physical skills for engineers. It is widely used in industry and engineering field for fluid dynamics, mechanical, electromagnetic, thermal and electrical simulations. In this work, convection heat transfer of solid cylinder in air is studied by using ANSYS Transient Thermal. ANSYS Workbench design modeler is used to create geometry of solid cylinder. Structural Steel is used to create geometry. The designed geometry consists of a solid cylinder having radius of 10 mm. The depth of solid cylinder is 40 mm.

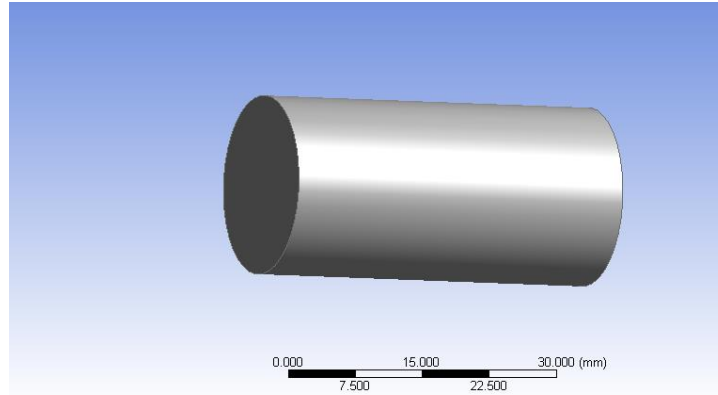


Fig. 2: Modeling of Solid Cylinder

To get more precise results or simulation, the geometry is exquisitely meshed with size element of 2 mm. The meshed setting contains moderate smoothing, admirable relevance center and fine span angle center. The meshed geometry has consisted of 6836 elements and 28510 nodes in total. The number of elements can be increased for more accurate results. But this finer meshing has drawback of processing time in simulation.

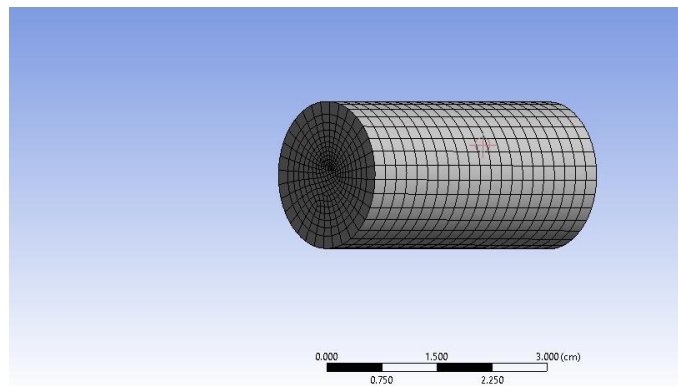
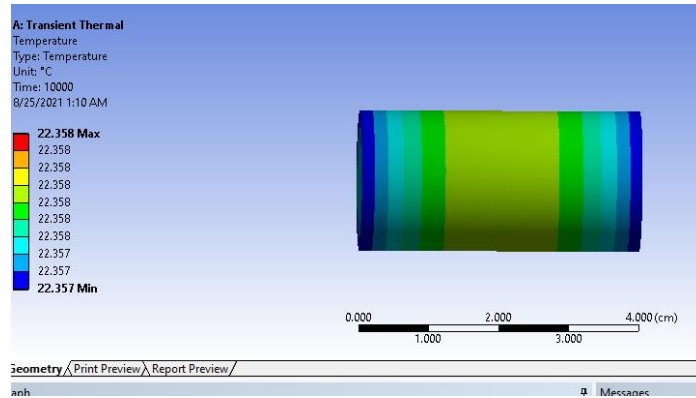


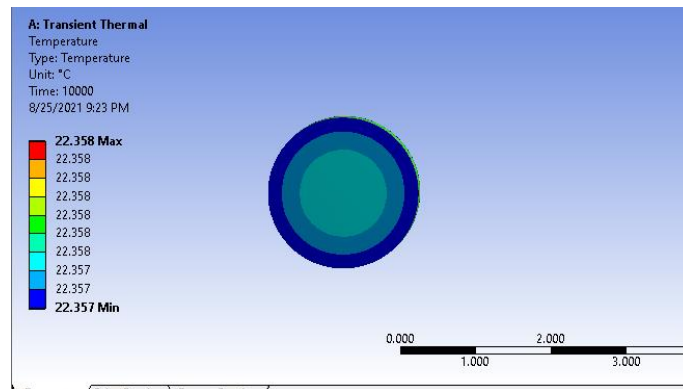
Fig. 3: Meshing of Solid Cylinder

Results and Discussion

ANSYS Transient Thermal is used to observe the convection heat transfer and cooling rate of the solid cylinder through air. The initial temperature given to the solid cylinder is 120°C. The Ambient temperature of the surrounding of the solid cylinder is 22°C. When we apply convection coefficient of $1 \times 10^{-5} \text{ W/mm}^2\text{°C}$, the Structural steel cylinder starts to cool with passage of time. At 2000s, the cylindrical structural steel showed the minimum temperature of 46.728°C at the edges. At 4000s, the cylindrical structural steel showed the minimum temperature of 29.293°C at edges. At 6000s, the cylindrical structural steel showed the minimum temperature of 24.43°C at the edges. At 8000s, the cylindrical structural steel showed the minimum temperature of 22.894°C at the edges and at the time of 10000s, the cylinder showed the minimum temperature of 22.357°C at the edges. The results show that the temperature decreases earlier from center of cylinder as compared to the edges of the cylinder.



(a)



(b)

Fig. 4 (a,b) : Result of decrease in Temperature from the edge of the cylinder

Table: Time vs Temperature

Temperature with respect to time at convection heat coefficient of $1 \times 10^{-5} \text{ W/mm}^2 \text{ } ^\circ\text{C}$		
Serial No.	Time (seconds)	Temperature (Celsius)
1-	2000s	46.728°C
2-	4000s	29.293°C
3-	6000s	24.43°C
4-	8000s	22.894°C
5-	10000s	22.357°C

These results show that cooling rate is rapid at the start of simulation and decrease gradually with increase in time. The graph for the decrease in temperature with respect to time is shown in figure.

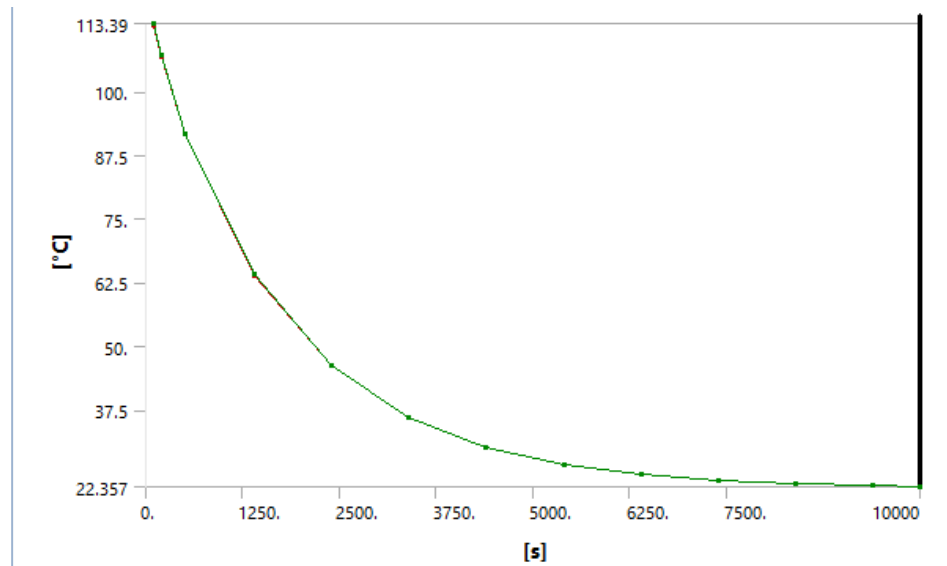
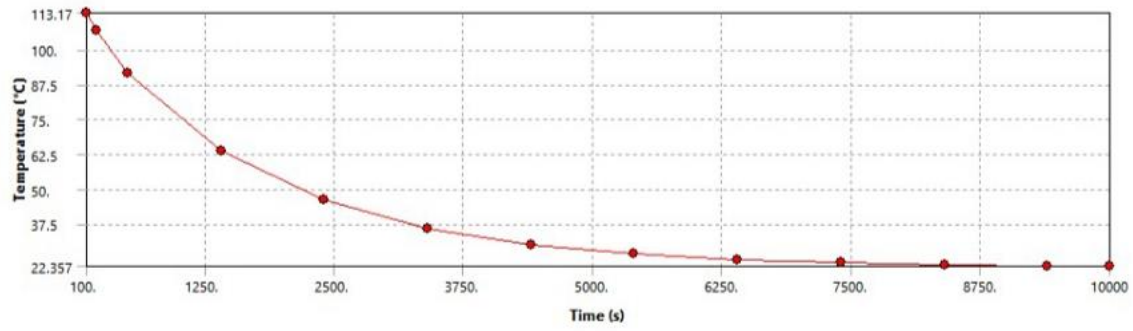
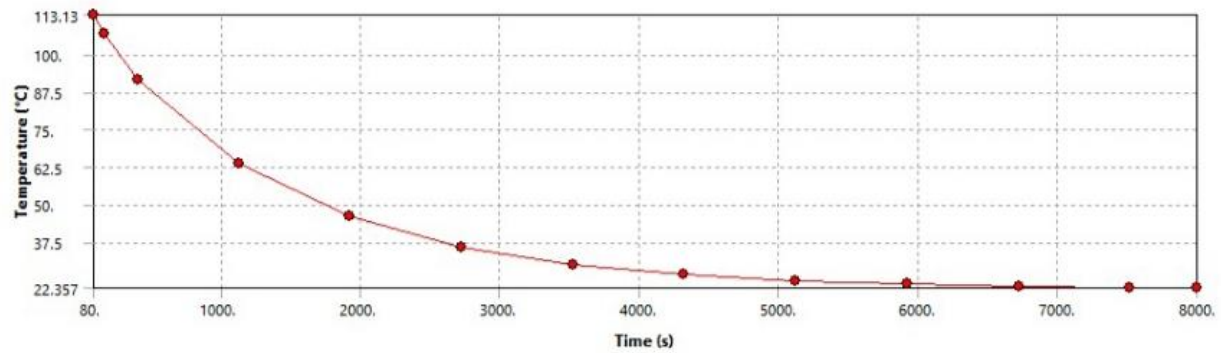


Fig. 5: Plot between temperature and time

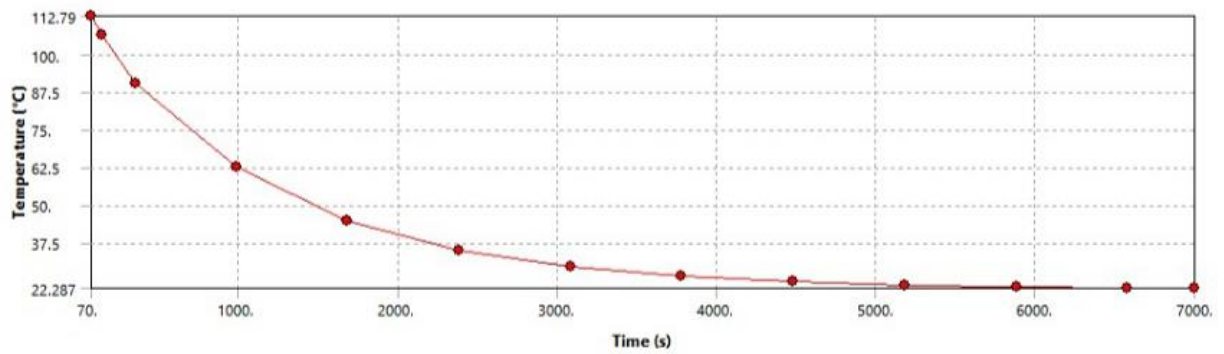
ANSYS Transient thermal is also used to observe the cooling rate with respect to convection heat coefficient. At convection heat coefficient of $1 \times 10^{-5} \text{ W/mm}^2\text{°C}$, the steel cylinder cooled down to temperature 22.357°C in 10000s. When we increase the convection heat coefficient, it has favorable impacts on the cooling rate. At convection heat coefficient of $1.25 \times 10^{-5} \text{ W/mm}^2\text{°C}$, the steel cylinder cooled down to temperature 22.357°C in 8000s. At convection heat coefficient of $1.5 \times 10^{-5} \text{ W/mm}^2\text{°C}$, the steel cylinder cooled down to temperature 22.287°C in 7000s. At convection heat coefficient of $1.75 \times 10^{-5} \text{ W/mm}^2\text{°C}$, the steel cylinder cooled down to temperature 22.287°C in 6000s. At convection heat coefficient of $2 \times 10^{-5} \text{ W/mm}^2\text{°C}$, the steel cylinder cooled down to temperature 22.56°C in 4500s. At convection heat coefficient of $2.2 \times 10^{-5} \text{ W/mm}^2\text{°C}$, the steel cylinder cooled down to temperature 22.755°C in 3800s. These simulations show that heat transfer (cooling rate) of steel cylinder has directly related to the convection heat coefficient. The plotted graph showed that with the increased value of convection heat coefficient make the heat transfer (cooling rate) faster. These results from ANSYS simulation shows the same behavior with the previous researches as with the results of M. Saidi et al. [5]. The different graphs between temperature and time related to different convection heat coefficient are given below:



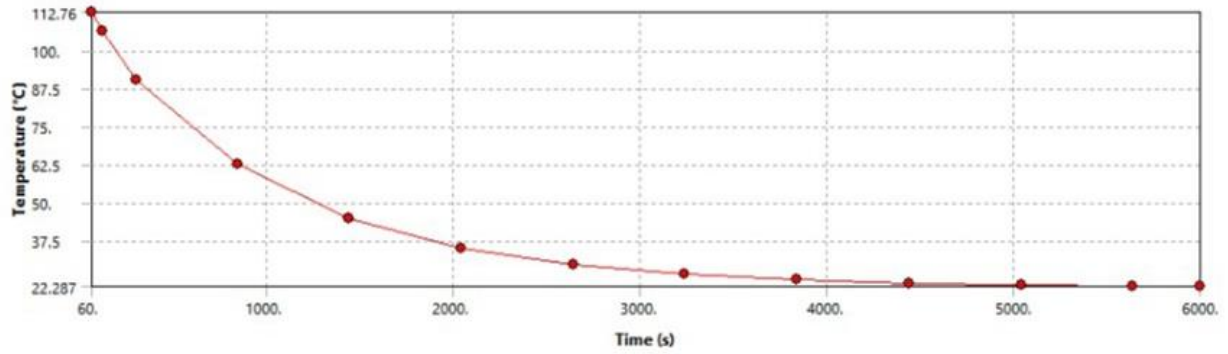
Graph. 1 (a): At convection coefficient of $1 \times 10^{-5} \text{ W/mm}^2 \text{ } ^\circ\text{C}$



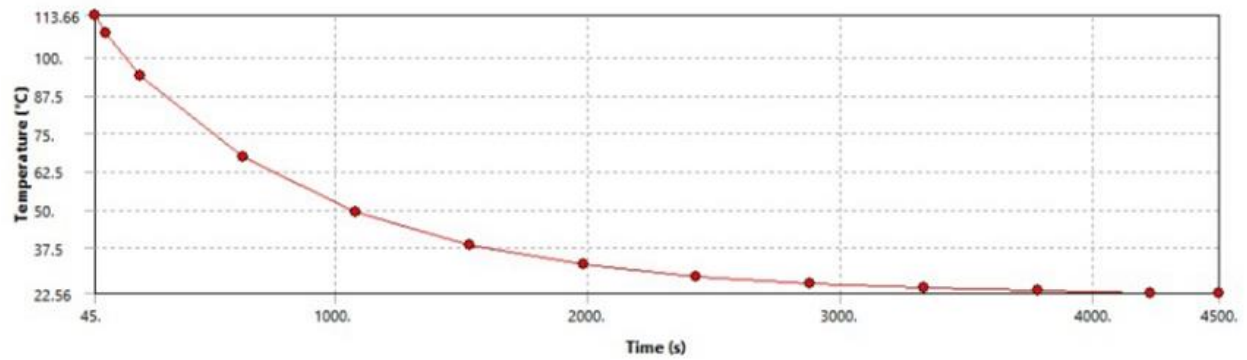
Graph. 1 (b): At convection coefficient of $1.25 \times 10^{-5} \text{ W/mm}^2 \text{ } ^\circ\text{C}$



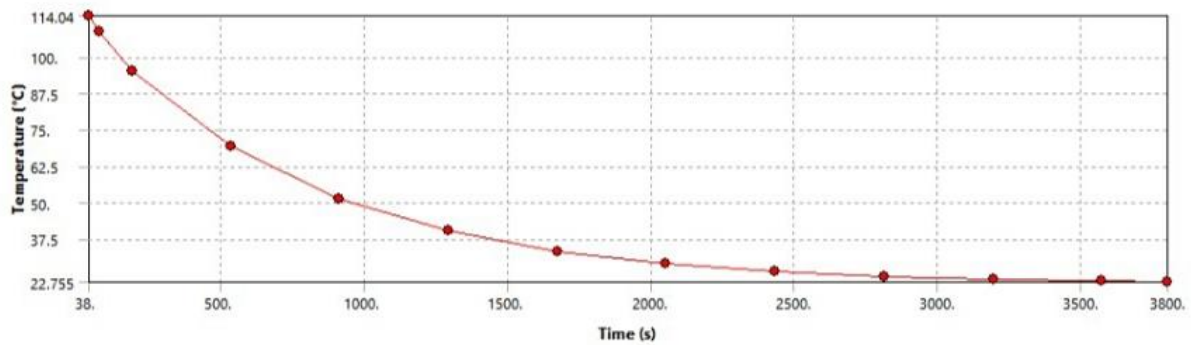
Graph. 1 (c): At convection coefficient of $1.5 \times 10^{-5} \text{ W/mm}^2 \text{ } ^\circ\text{C}$



Graph. 1 (d): At convection coefficient of $1.75 \times 10^{-5} \text{ W/mm}^2 \text{ } ^\circ\text{C}$



Graph. 1 (e): At convection coefficient of $2 \times 10^{-5} \text{ W/mm}^2 \text{ } ^\circ\text{C}$



Graph. 1 (f): At convection coefficient of $2.2 \times 10^{-5} \text{ W/mm}^2 \text{ } ^\circ\text{C}$

The graph for natural convection heat transfer (cooling rate) with respect to time and convection coefficients are shown in figures.

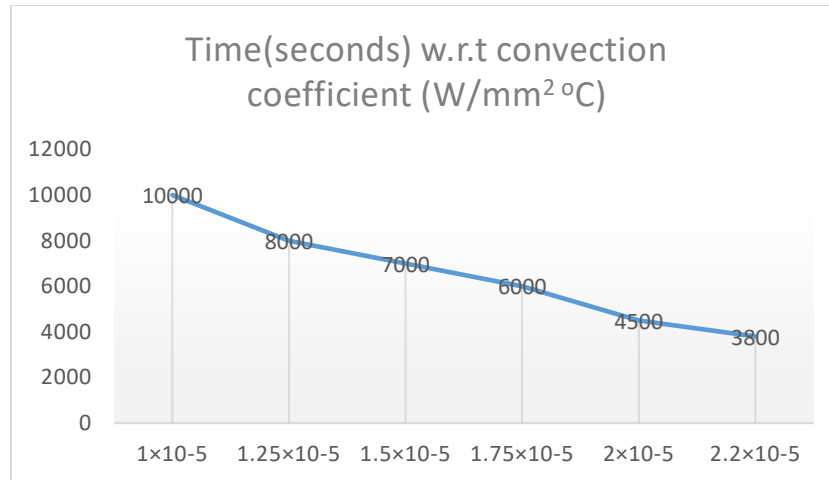


Fig. 6: Plot

Conclusion

In this paper, natural convection heat transfer is used for cool down the steel cylinder by using ANSYS Transient Thermal. For this purpose, a steel cylinder is designed having radius of 10 mm and depth 40 mm. The temperature of the steel cylinder is given $20^\circ C$ and ambient temperature of the surrounding was given $120^\circ C$. When we apply convection coefficient of $1 \times 10^{-5} W/mm^2 \text{ } ^\circ C$, the steel cylinder starts to cool with passage of time. The results show that the temperature decreases earlier from the center as compared to the edges of the cylinder. The temperature decreases from $120^\circ C$ to $22.357^\circ C$ in 10000 seconds. These results show that cooling rate is rapid at the start of simulation and decrease gradually with increase in time. When we apply our final convection coefficient of $2.2 \times 10^{-5} W/mm^2 \text{ } ^\circ C$, the temperature decreases from $120^\circ C$ to $22.755^\circ C$ in 3800 seconds. These simulations show that heat transfer (cooling rate) of steel cylinder has directly related to the convection heat coefficient.

Author's Contribution: M. A. M. Shahid. conceived the idea, designed the simulated work, did the acquisition of data, executed simulated work and wrote the basic draft. M. A. M. Shahid, M. T. Khan and F. Javaid did data analysis or analysis and interpretation of data and did the language and grammatical edits or critical revision.

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