Design and Analysis of Heat Exchanger with Nano Coating

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Abstract - *Nowadays heat exchangers are used commonly in industries to transfer heat. The transferring of heat is carried out by two process such as convection and radiation. Due to convection and radiation, the wear and tear will be obtain on surface of heat exchanger. So, it reduces the efficiency of heat exchanger to transfer the heat. Also the life expectancy of the heat exchanger will be reduce. Therefore the surface area of heat exchanger is going to modify which means coating will be done on surface area. Because of coating, the surface area of heat exchanger is increased, so the heat transfer rate also increased. Our project aims to do analysis of two material such as MgzrO8 with Ni Cr alloy which are used for coating on surface area of heat exchanger and find out which material is suitable to heat exchanger to transfer the heat. This will be done by using ANSYS software.*

Key Words: Heat exchanger, Nano Coating, Nano Materials (MgZrO8, Ni-Cr alloy), Blasting, Thermal Spray method, Analysis, ANSYS software, CATIA for design

1. INTRODUCTION

Heat exchanger is a device which is used to transfer heat from one region to another region easily. Heat exchangers are made up of copper and aluminium alloys. Because of their higher thermal conductivity and thermal expansion properties. There are lots of types of heat exchangers available for transferring the heat. Shell and tube heat exchanger is used mostly in industries. They are widely used in refrigeration system, thermal power plant, air conditioning, internal combustion engines, petroleum refineries, etc. For an example, taking internal combustion engine, the coolant flows through radiator coils and air (from blower fan) flows past the coils, which cools the coolant and heats the incoming air. In most heat exchangers, heat transfer between fluids takes place through a separating wall or into and out of a wall in a transient manner. In many heat exchangers, the fluids are separated by a heat transfer surface, and ideally they do not mix or leak. Such exchangers are referred to as direct transfer type, or simply recuperators. In contrast, exchangers in which there is intermittent heat exchange between the hot and cold fluids via thermal energy storage and release through the exchanger surface or matrix are referred to as indirect transfer type, or simply regenerators. Such exchangers usually have fluid leakage from one fluid stream to the other, due to pressure differences and matrix rotation/valve switching. Common examples of heat exchangers are shell and tube exchangers, automobile radiators, condensers, evaporators, air preheaters, and cooling towers. If no phase change occurs in any of the fluids in the exchanger, it is sometimes referred to as a sensible heat exchanger.

2. RADIATION AND CONVECTION

2.1 Radiaton

Thermal radiation, also known as heat, is the emission of electromagnetic waves from all matter that has a temperature greater than absolute zero. It represents the conversion of thermal energy into electromagnetic energy. Thermal energy consists of the kinetic energy of random movements of atoms and molecules in matter. All matter with a temperature by definition is composed of particles which have kinetic energy, and which interact with each other. These atoms and molecules are composed of charged particles, i.e., protons and electrons, and kinetic interactions among matter particles result in charge-acceleration and dipole-oscillation. This results in the electrodynamic generation of coupled electric and magnetic fields, resulting in the emission of photons, radiating energy away from the body through its surface boundary.

2.2 Convection

Convection is the heat transfer due to the bulk movement of molecules within fluids such as gases and liquids. Convection includes sub-mechanisms of advection (directional bulk-flow transfer of heat), and diffusion (non-directional transfer of energy or mass particles along a concentration gradient). Convection cannot take place in most solids because neither bulk current flows nor significant diffusion of matter can take place. Diffusion of heat takes place in rigid solids, but that is called heat conduction. Convection, additionally may take place in soft solids or mixtures where solid particles can move past each other.

3. NANOCOATING MATERIALS AND METHOD

The following nano particles are used to coating process and there are
1. Magnesium Zirconium Oxide (MgZrO8)
2. Nickel Chromium Alloy (Ni-Cr)

3.1 Properties of Magnesium Zirconium Oxide

1. Chemical formula - MgZrO8
2. Molar mass - 40.304 g/mol
3. Density - 7870 kg/m3
4. Melting point - 2852°C

5. Thermal conductivity - 161 W/m°C
6. Nanoparticle size - 30 nm
7. Thermal expansion - 0.000012 1/°C
8. Poison ratio - 0.27
9. Youngs modulus - 90000 Mpa

3.2 Nickel Chromium Alloy

Nickel Chromium Alloy Nanoparticles Nanoparticles, nanodots or nanopowders are high surface area nanoscale Nickel chromium alloy particles. American Elements manufactures nickel chromium alloy nanoparticles and nanopowder with standard particle size <100 nanometers (nm) and specific surface area (SSA) in the 5-50 m2/g range. They are also available as a dispersion through the AE Nanofluid production group. Nanodispersions are generally defined as suspended nanoparticles in solution either using surfactant or surface charge technology. Nanofluid dispersion and coating selection technical guidance is also available. Surface functionalized nanoparticles allow for the particles to be preferentially adsorbed at the surface interface using chemically bound polymers.

Properties of Nickel Chromium Alloy

1. Chemical formula - Ni-Cr
2. Molar mass - 101.96 g/mol
3. Density - 5600 kg/m3
4. Melting point - 1400°C
5. Thermal conductivity - 30 W/m°C
6. Nanoparticle size - 30 nm
7. Thermal expansion - 0.000008 1/°C
8. Poison ratio - 0.2
9. Youngs modulus - 46000 Mpa

3.3 Nano Coating Process

Nanocoating is coating that produced by usage of some-components at nanoscale to obtain desired proper-ties. Nanocoatings can be categorized as nanocrystalline, multilayer coatings with individual layer thickness of nanometers.

Step 1: Blasting

Abrasive blasting, more commonly known as sandblasting, is the operation of forcibly propelling a stream of abrasive material against a surface under high pressure to smooth a rough surface, roughen a smooth surface, shape a surface or remove surface contaminants. A pressurised fluid, typically compressed air, or a centrifugal wheel is used to propel the blasting material. Sandblasting can be carried out with a hand held gun, while shot blasting requires an enclosed space through which the workpiece is passed. There are several variants of the process, using various media; some are highly abrasive, whereas others are milder. The most abrasive are shot blasting (with metal shot) and sandblasting (with sand). Moderately abrasive variants include glass bead blasting (with glass beads) and plastic media blasting (PMB) with ground-up plastic stock or walnut shells and corncobs.

Fig -1: Blasting Process

Step 2: Thermal Spray Method

Thermal spray coatings are widely used as overlays to im-prove the performance of engineering materials and enhance their surface properties. The procedure involves spraying fine molten or semi-molten particles onto substrates to form a coating layer. The common processes include arc, flame, plasma, and high velocity oxy-fuel spraying. The microstructure of coatings is composed of lamella structure and other features such as porosity and oxides. In addition, the as-sprayed roughness is relatively high (Ra of about 3–40 μm). Thermal spray coatings have been widely applied to add functions such as wear resistance, corrosion resistance, bioactivity and dielectric properties to light metals. The characteristics of the deposition process, involving splat cooling and successive stacking of splats, create coatings of unique microstructure which are different from conventional materials. In this chapter the characteristics of the thermal spray processes, and factors influencing spray particle parameters are described. Generally thermal spray method done by using simple equipments in industries. So the cost of making nano coating on heat exchanger is low when compared to making heat exchangers by using nano coating materials. The material which is to be coated on heat exchanger is initially inserted in the machine, then it will be melted at particular temperature and sprayed over the heat exchanger tubes.

Fig -2: Thermal Spray method

4. DESIGN OF HEAT EXCHANGER

CATIA enables the creation of 3D parts, from 2D sketches, sheetmetal, composites, molded, forged or tooling parts up to the definition of mechanical assemblies. The soft-ware provides advanced technologies for mechanical surfac-ing & BIW. It provides tools to complete product definition, including functional tolerances as well as kinematics defini-tion. This software helps me to create this model of heat exchanger easily and effectively.

Fig -3: Heat exchanger Design

5. RESULTS AND DISCUSSION

5.1 Without Coating

(a) Analysis of Temperature Drop

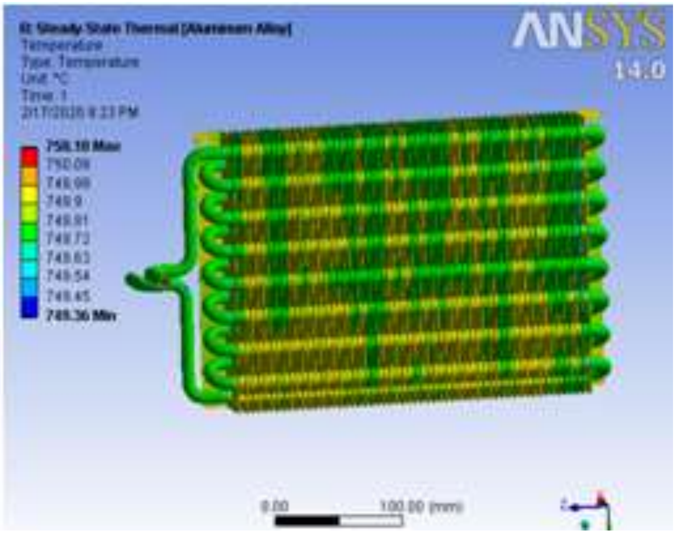

Fig -4: Temperature drop of Aluminium alloy without coating

(b) Heat flux of Aluminium Alloy

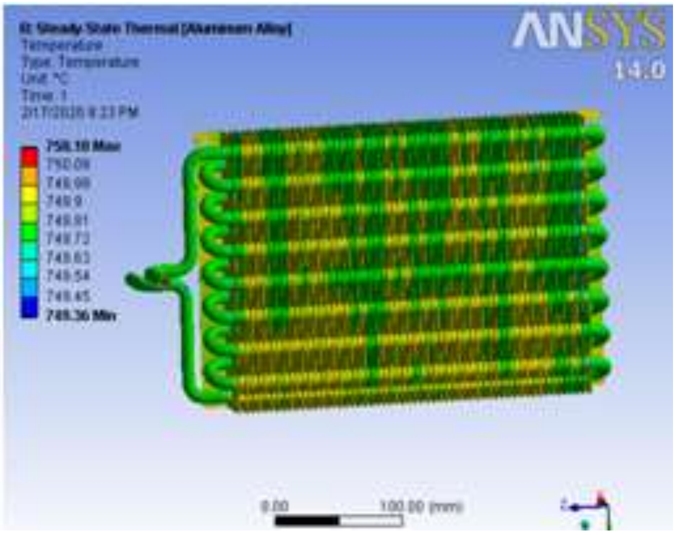

Fig -5 Heat flux of Aluminium alloy without coating

5.2 With MgZrO8 Coating

(a) Analysis of Temperature Drop

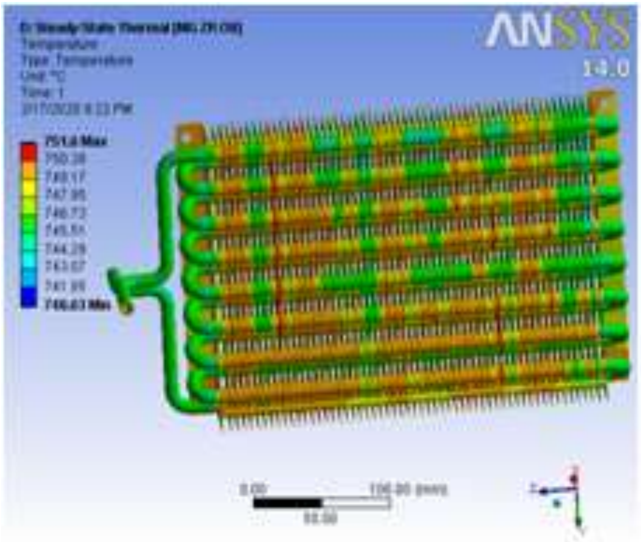

Fig -6: Temperature drop of Aluminium alloy with MgZrO8 coating

(b) Heat flux

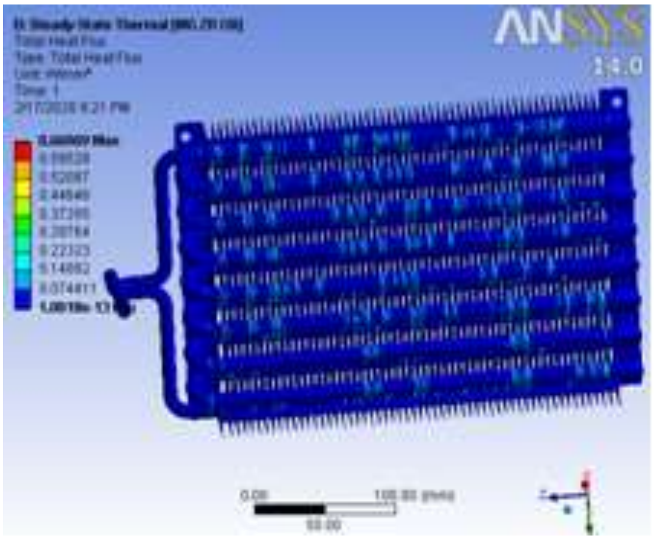

Fig -7: Heat flux of Aluminium alloy with MgZrO8 coating

5.3 With Ni-Cr Coating

(a) Analysis of Temperature Drop

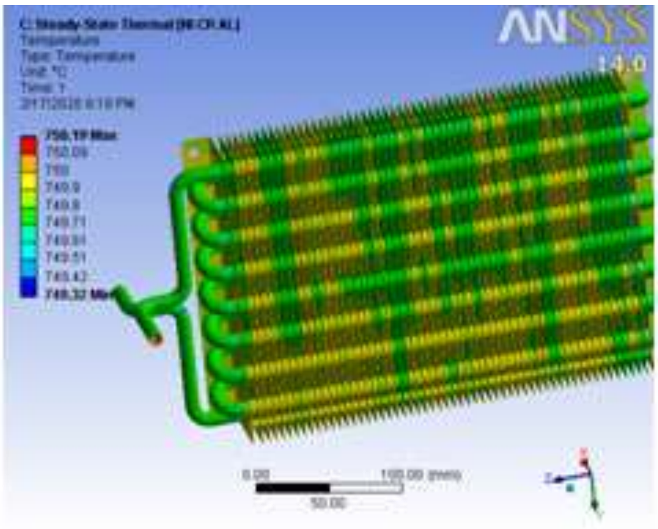

Fig -8 Temperature drop of Aluminium alloy with Ni-Cr coating

(b) Heat flux

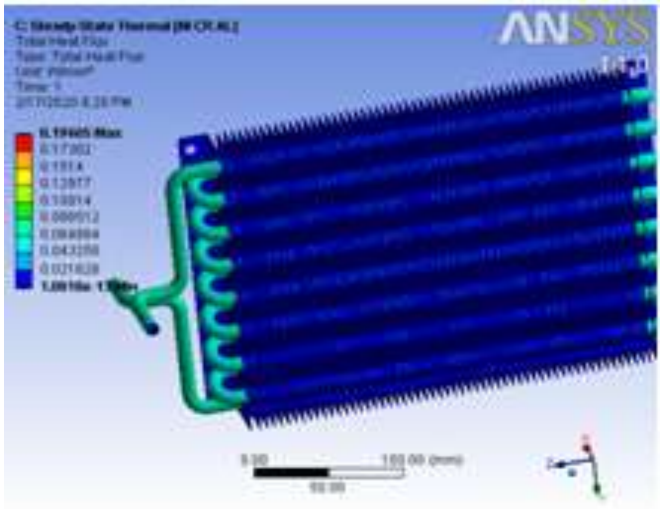

Fig -9: Heat flux of Aluminium alloy with Ni-Cr coating

5.4 Comparision of Results

Serial no	Materials	Temperature (°C)			Heat flux(W/m²)	
		Inlet	outlet	Temperature difference	Min	Max
1.	Aluminium alloy without coating	750	749.36	0.64	1.0818e^-13	0.1961
2.	Aluminium alloy with MgZrO8 coating	750	740.63	9.37	1.0818e^-13	0.6696
3.	Aluminium alloy with Ni-Cr coating	750	749.32	0.68	1.0818e^-13	0.1946

Fig -10: Results comparision

6. CONCLUSION

The analysis of heat transfer rate of the heat exchanger with-out coating and with coating has been completed. By comparing the results for each coating material used with the results of heat exchanger without coating, it is found that the heat exchanger coated with MgZrO8 has a higher heat transfer efficiency than the heat exchanger coated with Ni-Cr alloy. This is because the maximum heat flux generated by MgZrO8 is higher than Ni-Cr alloy which thereby increases the heat transfer rate. Hence MgZrO8 is the most suitable material for coating on the heat exchanger. This coating also increases the life expectancy of the heat exchanger as it acts as a protective layer over the heat transfer surface.

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