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Methodology of Material Selection for Evaporator Coil in Air Conditioning System

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Abstract— The ever-growing demand of air conditioning system in commercial and household application's emphasis on long-term material's stability. Material's failure in air conditioning system due to temperature variance and heat flow causing reduction in cooling effect of the system. Considerable amount of heat waste in evaporator coil as a result of low thermal transitions through coil's material resulting reduction in overall efficiency of the system. This paper provide a CES Granta's design software-based approach being followed to select appropriate material for evaporator coil in air conditioning system. Cast iron, pure titanium, copper, low alloy steel, Stainless steel, and nickel-chromium alloys are the shortlisted candidate for evaporator coil based on design and functional requirements. Low alloy steel, titanium, and stainless steel are the top suitable candidate among which stainless steel shows promising attributes for evaporator coil in air conditioning system. This paper will help the researchers, engineers, and designers to better understand the methodology of selecting a stainless steel in evaporator system to control corrosion and provide high- temperature-resistance.

Keywords— Material Selection, Evaporator, Granta's Design CES software

I. Introduction

Evaporation process are commonly practice in various Industries viz, food, beverages, paper, petrochemical, and water treatment in order to remove moister from the products. Evaporator technology has been around for many years as a variant technology. Concentration on pollution control and energy conservation are the main causes for variation in evaporator technology. In past various problems in evaporator system encountered by engineers either by adjustment of operation temperature and pressure or complete transformation of existing system into efficient one. The concentration of aggressive elements increase with discharge of waste stream causing corrosion and premature system failure [1]. Material selection is more critical for evaporator coil provided efficient cooling system and pollution control by the process engineer. Low alloy steel has been used as an evaporator material but need to be upgraded in order to control corrosion problem. Stainless steels have been and will continue to be used in many industries for evaporation purposes. Stainless steel provide effective corrosion resistance, excellent thermal properties from very low to high temperature applications. Evaporating service having wider applications now utilize stainless steel due to high-temperature resistance and corrosion care.

Material plays important role in engineering design. Without proper material, design product leads to pre-mature failure during operation. Each material has its own properties due to which one can differ it from other. Material selection is a process of finding best match material for an engineering product. Granta's design CES (Cambridge engineering selector) provide a detail strategy and approach for materials selection introduced by Ashby et al., 2002 [2].

Ashby et al, 2009 [3] utilizing Cambridge Engineering Selector software compared various materials based on design and functional attribute's requirements. The methodology followed the basic principle of defining function, constrains, objectives, and free variables for specific applications. All the materials present in the universe are considered as a candidate materials for the applications. Applying design and functional requirements screen out the failed materials. The remaining material ranked based on material indices. Weight property index method calculate the performance value of each shortlisted candidate's material. Material with highest performance is the final selected material.

Evaporator Coil is the most important component in air conditioning system. Refrigerants is heated in the coil and transmitting the heat away in order to cool the room air. Refrigerants varies based on operation conditions. Evaporator material must have corrosive resistant, higher tensile strength and high melting point because the refrigerant conversion into vapor due to high temperature must not exceed the material's melting point in order to have heat transformation with an environment [4].

Shanian et al, 2004 [5] utilized CES approach for material's selection based on production cost analysis. Multiple decision making properties were investigated for selecting material for engineering products. Materials were ranked from best to poor for covering cylinder to withstand static load and control conditions to room temperature.

Sommariva et al, 2003 [6] generated database for phase changing materials using CES edupack. The software listed the commercial and non-commercial phase changing materials based on temperature ranges from -50 ℃ to 150 ℃. Callister et al, 2012 [7] made selection of phase change materials such as 88Al-22Si for higher temperature applications considered thermal properties and environmental performance.

Heating, Ventilation, and Air conditioning (HVAC) coils utilized aluminum and copper tubes due to higher thermal conductance and lower cost. Stainless steel offers durable and corrosion resistance attributes, making them a wise choice for corrosive surroundings. Stainless steel has high strength but cannot transfer heat as effectively as aluminum tubes. Combining stainless steel tubes with aluminum fins are a future recommendation for effective heat transfer and lower cost in evaporator system [8].

Salty water or refrigerants that cause corrosion and leakage to the evaporator system can be reduced by utilizing stainless steel because of higher corrosion resistance offered by stainless steel. The Cambridge Engineering Selector approach used in this project will provides detail methodology for selecting stainless steel in evaporator's coils in HVAC system.

II. Methodology for Material Selection

Granta Design Selector (CES) is used to give a methodology for selecting a suitable material for any product design. Design and functional attributes are considered for selection purposes. Evaporator coil perform the function of extracting heat and transfer it outside to provide cooling effect to the conditioning systems. Design attributes include thermal, mechanical and corrosive properties. Thermal properties includes higher melting points, thermal conductance, and service temperature. Other attributes such as mechanical consists tensile strength and toughness, and corrosion resistance. The salty water and refrigerants causing corrosion to the evaporator coils need to be controlled by selecting higher corrosion resistance materials. The evaporator coils required attributes are given in Table 1. Based on the CES classification of material's universe into six categories are metals, polymers, ceramics, composites, elastomers and glasses, materials with higher melting point compared to evaporation system, having higher thermal conductance. Corrosion resistance, toughness and tensile strength would be the most promising material. Specifications and attributes specified for evaporator coil given in Table 1 identified the metals as a promising category out of six.

Table 1: Evaporator coil materials desirable properties

Property	Desirable Categorizations
Thermal	Higher melting point >730 ℃, higher thermal conductivity.
Mechanical	Higher Strength and Toughness
Corrosion	Must have higher corrosion resistance

The evaporator turns the liquid substance into gaseous or vapor form by absorbing heat from the system. Material must follow the emphasis constrains by the designer for effective evaporation systems. These restrictions are high melting pint, thermal conductivity, service temperature durability without corrosion, toughness and higher strength. The main goal is to achieve effective evaporation system for conditioning system. Material and dimension can be varied freely as a choice of designer. Table 2 describes the detail function, objectives, constrains, and free variables of evaporator coils in air conditioning systems.

Table 2: Function, objectives, constraints, free variable for evaporator coil's material

Function	• Evaporation
Constraints	• Higher melting point • Strong i.e. tensile strength • Greater Fracture Toughness • High Thermal conductivity
Objectives	• Maximize thermal conductivity • Minimize corrosion • Maximize strength • Minimize mass
Free Variables	• Choice of material • Dimension of coil

Following the Fig.1 to Fig. 4, illustrates various attributes such as melting points, thermal conductivity, tensile strength, and toughness of the metal alloys. Based on these properties, material is shortlisted for evaporator coil in conditioning system. Figures clearly shows the stainless steel, low alloy steel, titanium, nickel chromium, copper, and cast iron comes within the range specified after application of conditions and constraints. Apart from the above attributes, other properties that needs to be considered are service temperature, thermal diffusivity, and durability. Selecting the most promising material for evaporator system from the shortlisted candidate is the main challenge for designer.

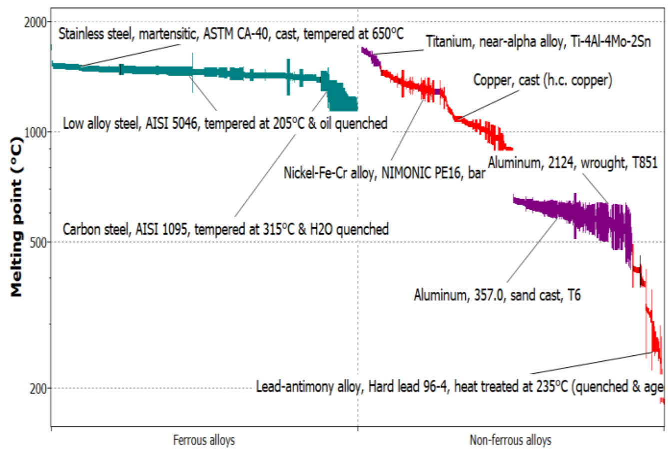


Figure 1; illustrate the melting points (℃) plotted on x-axis against the ferrous and non-ferrous alloys on y-axis.

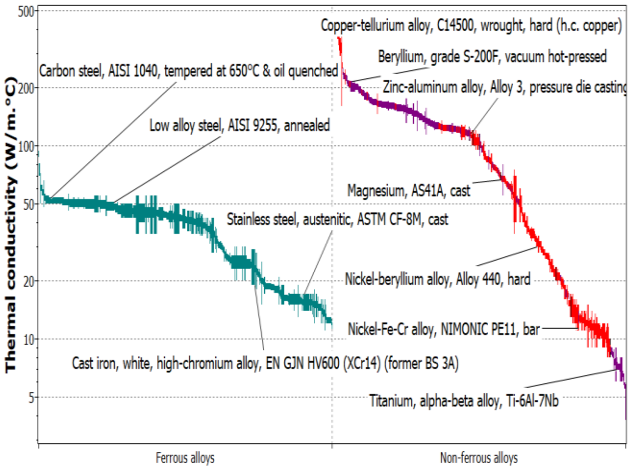


Figure 2; preview the thermal conductivity (W/m.℃) of ferrous and non-ferrous alloys plotted on x-axis and y-axis respectively using CES software.

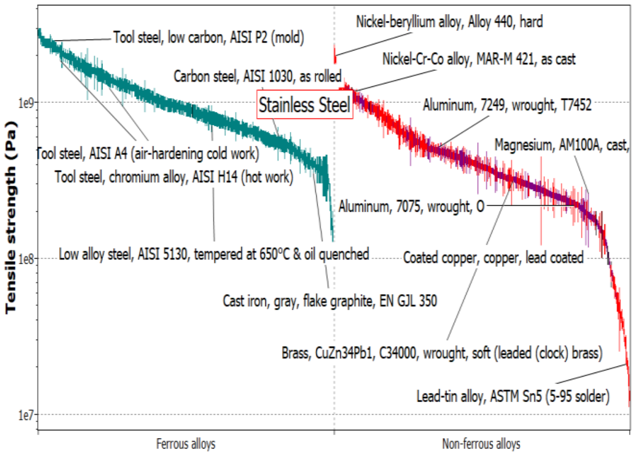
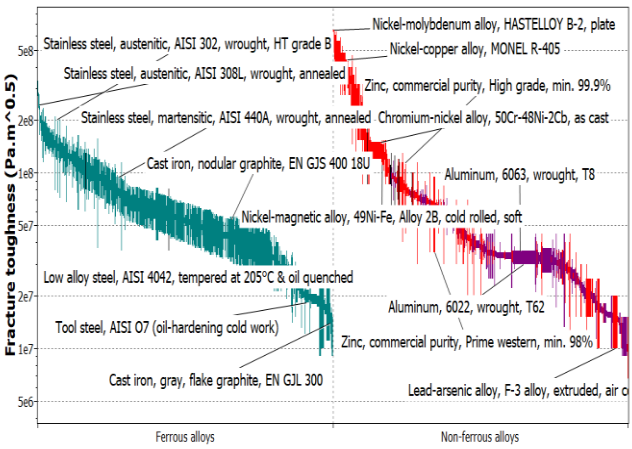


Figure 3; Tensile strength (Pa) plotted on y-axis against the metal alloys mentioning the shortlisted materials for evaporator coil operating conditions.



Figure; 4 Illustrate the fracture toughness (Pa.m^0.5) against the metal alloys.

From Figure 1-4, the following materials are listed as the promising candidate for evaporator system in air conditioning systems. The various attributes of the shortlisted candidate are given in Table 3.

TABLE 3: SHORTLISTED CANDIDATE FOR EVAPORATOR COILS IN AIR CONDITIONING SYSTEM

Materials	Comment
Cast iron	Cheap, easily available but corrosive
Commercially pure titanium	Lighter, high tensile strength but expensive
Copper	High thermal conductivity but expensive
Low alloy steel	Heavy but greater toughness
Stainless steel	Benchmark
Nickel Chromium Alloy	Corrosive resistant

Table 3 enlisted the cast iron, copper, low alloy steel, stainless steel and nickel-chromium steel selected from the Figure 1 to 4 based on design and functional requirements of the evaporator coil in conditioning system. Titanium addition to the list in Table 3 is because of the additional and supportive information gathered according to the application specifications.

III. PERFORMANCE CALCULATION (WEIGHT INDEX PROPERTY METHOD)

Material indices is a general expression of the parameters that optimize the desire performance based on the dependable factors. A brazed plate heat exchangers designed as an evaporator is used to transfer heat between the refrigerant and heat transfer fluid. Heat flux through evaporator is basically the heat transfer per unit area also known as heat exchanger's density. The equation (1) and (2) gives the required parameters for effective heat transfer between heat transfer fluid and refrigerants.

$$Q = k.\ A.\ MTD \qquad (1)$$

$$Q/A = k.\ MTD \qquad [W/m^2] \qquad (2)$$

Where:

Q= Capacity [W]

A= Heat transfer area [m^2]

k= Overall heat transfer Coefficient [W/m. K]

MTD= Mean Temperature Difference [K]

The heat transfer density depend upon the mean temperature difference and overall coefficient which is thermal conductivity. To maximize the evaporator capacity, temperature difference and thermal conductivity should be higher. Material with high thermal conductance, melting points, and corrosion resistance will be prefer over the rest of the candidate materials.

TABLE 4: PROPERTIES OF SHORTLISTED CANDIDATE MATERIALS TAKEN FROM CES DATABASE

Material	**Property**			
	Melting Point (℃)	**Thermal Conductivity (W/m.℃)**	**Tensile Strength (Pa) e^8**	**Toughness (Pa.m^0.5) e^7**
Cast Iron	1200-1430	37-40	1.1-1.4	1-1.6
Titanium	1660-1680	20.4-22.1	2.4-5.5	5-5.5
Low Alloy Steel	1460-1510	41-45	6.52-7.20	1.03-1.17

Stainless Steel	1430-1470	12-15	5.15-7.15	1.32
Nickel-Chromium Steel	1320	9-12	9.05-10.02	10.02
Copper	1030-1050	65-70	5-5.9	5.43

Two different scales are set for calculation of performance criteria. Ascending order of the attribute from most important to less importance is arranged based on design and functional requirements of the evaporator coil in conditioning system. The scale vary from 1 to 5. The property nature is assigned from excellent to poor value on scale 0 to 1. Melting point is at the top of the scale and toughness is the least important one. The summation of importance on scale 1 to 5 against the property is represented by ∑r = 14. While performance weightage calculated is shown in Table 5.

TABLE 5. PERFORMANCE WEIGHTAGE OF SHORTLISTED CANDIDATE FOR EVAPORATOR COIL

Material	**Property**						
	Corrosion resistance	M.P (℃)	K (W/m.℃)	Tensile Strength (Pa) e^8	Toughness (Pa.m^0.5)ve^7	∑R	∑R/r
Cast Iron	X	5*0.4= 2.0	4*0.8= 3.2	3* 0.1= 0.3	2*0.4= 0.8	6.3	0.45
Titanium	S	5*0.6=3	4*0.6= 2.4	3*0.8= 2.4	2*0.6= 1.2	9	0.64
Copper	S	5*0.1= 0.5	4*1= 4	3* 0.6= 1.8	2* 0.8= 1.6	7.9	0.56
Low Alloy Steel	S	5*1= 5	4*0.6= 2.4	3* 0.4= 1.2	2*0.8= 1.6	10.2	0.729
Stainless Steel	S	5*0.8= 4.0	4*0.8= 4.0	3*0.8= 2.8	2*0.4= 0.8	10.4	0.74
Nickel Chromium Alloy	S	5*0.4= 2.0	4*0.4= 1.6	3*1= 3	2*1= 2	8.6	0.61

CONCLUSION

Evaporators are widely employed in most industries that depend on a constant supply of fluids or chemicals, and ideal for very low temperature applications in the food and pharmaceutical industries. Evaporator material failure occurs due to heat and aggressive particle present inside the conditioning system. Pitting corrosion take place inside the evaporator tubes because of chlorine and salty water circulating through the tubes. Stainless steel offer high strength along with higher corrosion resistance. Stainless steel gives promising performance in evaporating coils. The long-term stability of stainless steel over lower alloy steel and titanium made it final choice for evaporator coil in air conditioning system.

REFERENCES

[1] Wiqas Alam Material Selection for Micro Channel Heat Exchangers for Industrial Waste Heat Recovery International Journal of Engineering Works Vol. 6 Issue 11 PP. 406-413 November 2019

[2] Zupan, Marc, Mike F. Ashby, and Norman A. Fleck. "Actuator classification and selection—the development of a database." Advanced engineering materials 4.12 (2002): 933-940

[3] Schodek, Daniel L., Paulo Ferreira, and Michael F. Ashby. Nanomaterials, nanotechnologies and design: an introduction for engineers and architects. Butterworth-Heinemann, 2009.

[4] Reddy, G. Prashant, and Navneet Gupta. "Material selection for microelectronic heat sinks: an application of the Ashby approach." Materials & Design 31.1 (2010): 113-117.

[5] Shanian, A., and O. Savadogo. "A methodological concept for material selection of highly sensitive components based on multiple criteria decision analysis." Expert Systems with Applications 36.2 (2009): 1362-1370.

[6] Sommariva, Corrado, Harry Hogg, and Keith Callister. "Cost reduction and design lifetime increase in thermal desalination plants: thermodynamic and corrosion resistance combined analysis for heat exchange tubes material selection." Desalination 158.1-3 (2003): 17-21.

[7] Sommariva, Corrado, H. Hogg, and K. Callister. "Forty-year design life: the next target Material selection and operating conditions in thermal desalination plants." Desalination 136.1-3 (2001): 169-176.

[8] Anojkumar, L., M. Ilangkumaran, and V. Sasirekha. "Comparative analysis of MCDM methods for pipe material selection in sugar industry." Expert systems with applications 41.6 (2014): 2964-2980.).