COOLING SYSTEM IN TIG WELDING BY USING VAPOUR COMPRESSION CYCLE

Prof. Tushar Patil[1], Swapnil More[2], Rajendra Pawar[3], Ganesh Patil[4], Pradeep Bhadane[5]

[1]*Prof. Mechanical, Mechanical, SIEM, Nshik, Maharashtra, India*

[2,3,4,5] *BE Student, Mechanical, SIEM, Nashik, Maharashtra, India*

Abstract - *Tungsten Inert Gas (TIG) welding is also known as Gas Tungsten Arc Welding (GTAW) process which is an arc based welding process that uses the arc between a non-consumable tungsten electrode and a work piece with the help of a shielding gas. The purpose of this study is to lower the temperature of water used as a coolant in TIG welding. The Vapour Compression Cycle is similar to reversed Carnot cycle. In this study the Vapour Compression Cycle is implemented in order to reduce or lower the temperature of water used as coolant in TIG welding. The TIG welding with water cooling was used to weld high strength plates. The weld properties including mechanical properties and microstructure were analyzed. The numerical simulation result revealed that water cooling method used in TIG welding is greatly helpful in reducing the volume of the welding pool due to the enhanced cooling effect. Additionally, improved holding power of the welding pool can be obtained due to the increased surface tension. The Vapour Compression refrigeration Cycle (VCC) system plays an important role and accounts for a large proportion of energy consumption from heating ventilating and refrigeration system. The recent technologies such as sub-cooling cycles, multi-staging cycles are used to increase COP of Vapour Compression Cycle*

Key Words: **Tungsten Inert Gas Welding, Vapour Compression Cycle, Condenser, Evaporator, TIG Torch, Tungsten Rod, Compressor**

1. INTRODUCTION

TIG stands for Tungsten Inert Gas and is technically called Gas Tungsten Arc Welding or GTAW. The process uses a non-consumable tungsten electrode that delivers the current to the welding arc. GTAW normally since most applications require that the welder manually feed a filler metal into the weld area with one hand while manipulating the welding torch in the other. Maintaining a short arc length, while preventing contact between the electrode and the work piece is also important. To strike the welding arc, a high frequency generator provides an electric spark. This spark is a conductive path for the welding current through the shielding gas and allows the arc to be initiated while the electrode and the work piece are separated, typically about 1.5–3 mm. Once the arc is struck, the welder moves the torch in a small circle to create a welding pool, the size of which depends on the size of the electrode and the amount of current. While maintaining a constant separation between the electrode and the work piece, the operator then moves the torch back slightly and tilts it backward about 10–15 degrees from vertical. Filler metal is added manually to the front end of the weld pool as it is needed.

The TIG welding generates a huge temperature of 2800-3400, due to which the temperature of work piece also increases and becomes difficult to handle. The temperature of TIG torch also increases and gets difficult to weld. The existing system was made in which water circulation is done around the TIG torch through copper pipe to reduce the temperature of TIG torch. But for using the machine longer time the temperature of water which is circulated also gets increased.

In this project we implement the vapour compression cycle for cooling the water. The vapour-compression uses a circulating liquid refrigerant as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat elsewhere. Single-stage vapour-compression system has four components a compressor, a condenser, a thermal expansion valve, and an evaporator. Circulating refrigerant enters the compressor in the thermodynamic state known as a saturated vapour and is compressed to a higher pressure, resulting in a higher temperature as well; the hot compressed vapour is at a temperature and pressure at which it can be condensed with either cooling water or cooling air flowing across the coil or tubes. The refrigerant rejects heat from the system and the rejected heat is carried away by either the water or the air. The condensed liquid refrigerant is next routed through an expansion valve where it undergoes an abrupt reduction in pressure. That pressure reduction results in lowering the temperature of the liquid and vapour refrigerant mixture to where it is colder than the temperature of the enclosed space to be refrigerated.

2. OBJECTIVE

The Vapour Compression cycle (VCC) is implemented in TIG welding process. The main objective or aim is to reduce the temperature of coolant (water) before circulating it to the welding torch. If the temperature of the coolant falls below the atmospheric temperature, this will results in more operating time and hence production rate will increase, more efficient welding occurs. It will provide good appearance to welding and enhances the strength of the welding.

3. PROBLEM STATEMENT

The TIG or tungsten inert gas welding process which is an arc based welding process in which welding torch normally uses a constant current ranging 5-300 A or higher and voltage ranging from 10-35 V which is tremendous. Here the water cooling system is used in which the water is circulated through the welding torch. If the circulation of water continuous the heat transfer between welding torch and water take place, If the process continuous for 2-3 hrs. The temperature of coolant water reaches to a temperature of 45-50^{0}C. If this water is circulated continuously, it will affect the efficiency of welding, blow holes will be produced and develops porosity and give the poor strength to the welding, which is the drawback of the TIG welding. To reduce the temperature of cooling water to overcome the drawbacks of TIG welding is the aim of this project.

4. TECHNICAL SPECIFICATIONS

Materials	**Application**
Compressor	1/6 HP
Relay	for electrical connections
1/4' copper tube	for evaporator (20 feet)
1/4' copper tube	for condenser (25 feet)
Capillary tube	for expansion (8 feet)
Condenser Air-cooled	for condensing the liquid
Filter drier	Dehydrator
Thermostat	Automatic defrost control
Gas	(R134a) Refrigerant (1200 gm)
Oil	lubrication purpose
Brazing rod	brazing the tubing
Fan	cooling the condenser
Puff material	tank insulation purpose
Tank	storing water (0.5m×0.4m×0.3m)
Digital temp indicator	indicating water temperature
Capacitor	storing the charge
TIG welding machine	provide constant current power source with welding current Ranging from 3-200A
TIG torch	to weld thin and thick component

5. DESIGN CALCULATIONS

Tank dimensions are follows:

Length of the tank is 500 mm, Width of the tank is 300 mm, and Height of the tank is 400mm

Volume of the tank =Length × Width × Height

$= 0.5 \times 0.3 \times 0.4$

$= 0.06\ m^3$ = 60 Liter =60k Kg

Mass of water in the tank is (m) = 50 Kg

Heat Rejected to the surrounding is given by,

$Q = m \times C_p \times \Delta T = 50 \times 4.187 \times (50-14) = 7536.6$ KJ

$= 7536.6/(3 \times 3600) = 0.6978$ KJ/s = 0.6978 Kw

1 Tank Volume = 60 liter
2 Heat rejected = 7536.6 KJ

When the welding process is started the temperature of water rises up to 50ºC in 3 hours. Therefore heat rejected by the compressor in 3 hours is 0.6978 KW.

Theoretical calculations

T_1= Inlet compressor temperature = 14ºC

T_2= Outlet compressor temperature = ?

T_3= Temperature after Condenser = 50ºC

T_4 = Inlet evaporator temperature = ?

Properties at given Temperature

C_{pf}= specific heat of water = 1.37 KJ/kgK

C_{pg} = specific heat of gas = 0.965 KJ/kgK

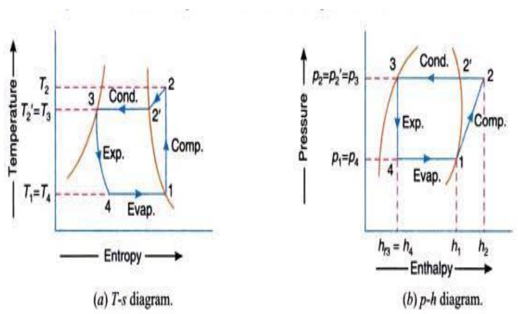

Fig.5.1. T-s and P-h Diagram

5.1. Compressor Capacity

Since $S_1=S_2$

Calculate T_2:-

$s_{g1}= s_{g2} + C_{pg} \ln(T_2/ T_{2'})$

$1.7207 = 1.7078+0.965 \ln(T_2/323)$

$T_2 = 327.34\ ^{\circ}K$

h_1=hg1

h_1 =406.60

h_1=406.60 KJ/kg

$h_2= h_2+C_{pg} (T_2- T_{2'})$

h_2=423.63+0.965(327.34-323)

h_2=427.81KJ/kg

$h_4= h_{f3}$

h_4 =271.6KJ/kg

Calculations Performance Parameters

1 Net Refrigerating effect(NRE)
= $(h_1- h_4)$
= (406.6-271.6)

=135KJ/kg

2 Circulating rate of refrigerant in Kg/Sec

R.E = $\dot{m}\ (h_1- h_4)$

0.6978 = $\dot{m}$ (135)

$\dot{m} = 5.16\times10^{-3}$ kg/sec

3 Heat of Compression
= $(h_2- h_1)$
= (427.81-406.6)

= 21.21 KJ/k

4 Compressor Power
= mass Refrigerant flow × Heat of Compression
$=5.16\times10^{-3}\times21.21$
=0.1094 Kw

5 Compressor Power in Hp
=(0.1094/0.1466)
=0.1466 Hp

6 Theoretical Coefficient of Performance
= (135/21.21)
=6.36

7 Condenser Work
= $(h_2- h_3)$
= (430.01-264.75)

=165.26 KJ/kg

5.2. Evaporator size

Diameter =6.35mm

Length=6.096m

5.3. Calculations for Condenser Length

Heat transfer coefficient of air (ho)

Physical properties of air at Temperature of air (Ta)= 30ºC is given below

Density =1.165 kg/ m^3

Dynamic Viscosity of air (μ) $=18.93\times10^{-6}$ N-s/ m^2

Specific Heat of air (C_p) =1.005 KJ/kg k

Thermal Conductivity of air (K) $=26.73\times10^{-3}$ W/m-k

Velocity of air fan = 5.5 m/sec

Face Diameter of fan=0.145m

Reynolds Number (Re) = $\frac{\rho\times V\times D}{\mu}$

$$= \frac{1.165\times5.5\times0.145}{18.93\times10^{\wedge}-6}$$

(Re)=49080.16

Prandtl Number (Pr) = $\frac{\mu\times Cp}{k}$

$$= \frac{18.93\times10^{\wedge}-6\times1.005}{0.02673}$$

=0.711

Nusselt Number (Nu) $=0.3\times Re^{0.6}\times Pr^{0.33}$

$=0.3\times (49080.16)^{0.6}\times (0.711)^{0.33}$

=173.89

Nusselt Number (Nu) = $\frac{ho\times D}{K}$

$$ho = \frac{173.89 \times 0.02673}{0.145}$$

h_o=32.05 w/m²k

Outer diameter of condenser coil (D_o) =6.35mm

Inner diameter of condenser coil (D_i) =4.826mm

A_o=3.166×10^{-5} m², A_i=1.83×10^{-5} m²

Refrigerant Properties at 50⁰c for R134-a

Dynamic Viscosity (μ) =142.7×10^{-6} N-s/ m²

Specific Heat of Refrigerant (Cp) =1.566 KJ/kg k

Thermal Conductivity (K) =71.05×10^{-3} W/m-k

Prandtl Number (Pr) =3.145

Reynolds number (Re) = $\frac{mr \times Di}{\mu \times Ai}$

$$= \frac{5.16 \times 10^{-3} \times 0.004826}{142.7 \times 10^{-6} \times 0.0000182}$$

Re =9588.30

Nusselt Number (Nu) = $\frac{ho \times D}{K}$

Nu =0.026× (9588.3)$^{0.8}$× (3.145)$^{0.4}$

=63.01

Heat transfer coefficient for refrigerant (hi)

$$h_i = \frac{Nu \times K}{Di}$$

$$h_i = \frac{63.01 \times (71.05 \times 10^{-3})}{0.004826}$$

h_i = 927.66 W/m²K

For overall heat transfer coefficient (U_o)

$$\frac{1}{Uo} = \frac{1}{hi} \times \frac{Ao}{Ai} + \left(\frac{1}{ho}\right)$$

For natural convection heat transfer coefficient is ho= 32 W/m²K

$$\frac{1}{Uo} = \frac{1}{927.66} \times \frac{3.166 \times 10^{-5}}{1.83 \times 10^{-5}} + \frac{1}{32.05}$$

U_o = 30.24 W/m²K

For finding out LMTD (Log mean temperature difference) we used coolpack software

LMTD = 19⁰c

Q = Condenser duty

= 697.8 Watt

By using relation of heat transfer equation

Q = U× A_o ×LMTD

697.8 = 30.24×A_o×19

A = 1.2144m²

A = π×D×L

1.2144 = π×0.00635×L

$$L = \frac{1.2144}{\pi \times 0.00635 \times 8}$$

L = 7.6 m

6 ASSEMBLY OF COOLING SYSTEM IN TIG WELDING

Following is the design of assembly in which the all components are assembled according to the design in which the connection of water supply from existing system is removed and it is connected to the new system. In new system water is cooled by using vapour compression refrigeration system and this cold water is stored in the tank which is insulated by puff material and supply the water to TIG welding torch.

Fig.6.1. Assembly of Vapour Compression Cycle with TIG machine

7. WORKING

During welding process the temperature of welding torch reaches to a temperature of 2800ºC to 3200ºC which is tremendous. Due to which the black spots as well as porosity is produced and strength of the welding is reduced.

To cope up with such conditions, the refrigeration cycle is implemented on the coolant liquid, before circulating the coolant for the welding process. Once the vapour compression cycle is implemented the temperature of coolant reduces below the atmospheric temperature. Cooled water is then circulated to the welding torch. By this process the drawbacks of TIG welding process can be eliminated and an efficient welding is produced and hence it gives good appearance and provides better strength.

The actual vapour compression cycle is explained below:-A vapour compression refrigeration system is a closed cycle refrigeration system. In this system, the refrigerant undergoes alternately a change of phase from vapour to liquid and liquid to vapour during the operation. The latent heat of vaporization is utilized for absorbing the heat from the refrigerated space.

This system consists of four main components: Evaporator, Compressor, Condenser, Expansion device. The high pressure liquid refrigerant coming out from the Condenser is passed through the throttle or expansion valve. The pressure of the refrigerant is reduced as it passes through the Throttle valve. The function of the throttle valve is to allow the liquid refrigerant under high pressure to pass at a controlled rate into the low pressure part of the system known as Evaporator. A low pressure liquid refrigerant enters the evaporator and absorbs the latent heat of evaporation and gets converted into saturated vapour. Compression of dry and saturated or superheated refrigerant is called dry compression. The vapour leaving the evaporator enters the Compressor where its temperature and pressure is increased so that the refrigerant vapour would be able to dissipate heat to the atmosphere. The high pressure, high temperature refrigerant vapour leaving the compressor enters into Condenser where the latent heat of refrigerant is removed by circulating either atmospheric air or water. The liquid refrigerant leaving the condenser again enters the Throttle valve and the cycle is repeated.

8. ADVANTAGES

- The ability to soft start and soft stop makes the TIG process different from other types of electric welding.
- Less wear and tear of tungsten rod.
- Life of the current supply wire increases and there is no heat produce in wire.
- Better handling of the TIG torch.
- Increases machining time. Therefore high rate of production.
- The coefficient of performance is quite high.
- It can be employed over a large range of temperatures.
- TIG welding is very much suitable high quality welding for thin material.
- Cleaner and more appealing joints. Sometimes they don't need finishing process.
- They are suitable for welding of very thin sections.

9. DISADVANTAGES

- The initial cost is high.
- The leakage of the refrigerant is the major problem in vapour compression cycle.
- It is significantly slower than most other welding techniques.
- More complicated - Highly skilled and professional workers are needed to perform TIG welding.
- Safety issue - Welders, are exposed to high intensity of light which can cause eye damage.

10. FUTURE SCOPE

The "Cooling System in TIG Welding by using Vapour Compression Cycle" can also be applicable in MIG welding. It enhances the production rate as well as improves the quality of the welding. It has a wide range of applications such as Automobile, Aerospace, and Marine and can also be used in small workshops. The liquid cooling systems becoming the priority cooling solution in the future, there is always a scope for education and economic viability. The cooling system is the most important factor in manufacturing sector.

11. CONCLUSION

By implementing the new cooling system in TIG welding, the machining time increases hence the production rate also increases and labor cost decreases. New cooling system in TIG welding the life of tungsten increases which saves cost. Supplying cooled water into TIG torch it becomes safe for handling the TIG torch. As the cooling water is supplied to

TIG torch it absorbs the heat generated by torch and the work piece does not gets heated too much.

ACKNOWLEDGEMENT

I am very glad to represent the paper on “Cooling System In TIG Welding by Using Vapour Compression cycle ”. I have try my best to focus upon each and every parameter. in concern with this topic details ,necessary figure, definition ,tabular analysis has been enumerated in very easy, simple, compact and lucid manner.

I have been able to achieve this task by the dynamic guidance of honorable Prof. T. D. Patil; because of his reference and guidance we able to fabricate as a machine.

I also extend my sincere thanks to our H.O.D. Prof. A. S. Dube, whose guidance and constant inspiration where a great use in working of this project. Last but not least, I am very thankful to my project partners without whose kind cooperation it was difficult and impossible to go through the leaps and bounds while preparing this project.

REFERENCES

[1] Refrigeration and Air-Conditioning –Domkundwar, Arora

[2] Wenfei Fan, Sansan Ao, Yifei Huang, Weidong Litu, Yang Li, Yueqiao Feng ‘Water cooling keyhole gas tungsten arc welding of HSLA steel’, Int J Adv Manuf Technol DOI 10.1007/s00170-017-0234-0, May 2017

[3] Bilal Ahmed Qureshi, Syed M. Zubair ‘Mechanical sub-cooling vapor compression systems: current status and future directions’, International Journal of Refrigeration (2013), doi:10.1016/j.ijrefrig.2013.07.026, 2013

[4] A.Baskaran1, P.Koshy Mathews2, ‘A Performance Comparison of Vapour Compression Refrigeration System Using Eco Friendly Refrigerants of Low Global Warming Potential’, International Journal of Scientific and Research Publications, Volume 2, Issue 9, September 2012, ISSN 2250-3153

[5] S. P. Arunkumar1, P. Koshy Mathews2 and C.Prabha3 ‘Performance Studies on Vapour Compression Refrigeration System’, International journal for research in emerging science and technology, volume-1, issue-5, october-2014

[6] Chasik Park, Hoseong Lee, Yunho Hwang, Reinhard Radermacher ‘Recent advances in vapor compression cycle technologies’, School of Mechanical Engineering, Hoseo University,Asan 336-795, Republic of Korea b Center for Environmental Energy Engineering, University ofMaryland, 4164 Glenn L. Martin Hall Bldg,College Park, MD 20742, USA.

[7] http://www.peacesoftware.de/einigewerte/r13a

BIOGRAPHIES

Prof. T. D. Patil
Mechanical, Engineering, SIEM, Nashik, Pune University, Maharashtra, India

Swapnil B. More
Mechanical, Engineering, SIEM, Nashik, Pune University, Maharashtra, India

Rajendra V. Pawar Mechanical, Engineering, SIEM, Nashik, Pune University, Maharashtra, India

Ganesh D. Patil
Mechanical, Engineering, SIEM, Nashik, Pune University, Maharashtra, India

Pradeep K. Bhadane Mechanical, Engineering, SIEM, Nashik, Pune University, Maharashtra, India