DESIGN AND CFD ANALYSIS OF SHELL AND TUBE HEAT EXCHANGER USING PLAIN TUBE AND CORRUGATED TUBE

Ramkrishna Gondane[1], Y. M. Jibhakate[2]
[1] PG Student, Mechanical Engineering Department, K.I.T.S., Ramtek, Maharashtra, India
[2]Associate Professor, Mechanical Engineering Department, K.I.T.S., Ramtek, Maharashtra, India

ABSTRACT

Shell and tube heat exchangers are used for convective heat transfer between two fluids, where one fluid flows through the tubes and other flows in the shell. This paper mainly focuses on improving the heat transfer capability in a shell and tube heat exchanger by varying tubes geometry using ANSYS Fluent. Study carried out the thermal design on the heat exchanger working in the company. Corrugated tube were employed instead of plain tube through a shell and tube heat exchanger. Corrugated tubes were investigated for heat transfer coefficient is studied for a shell and tube heat exchanger made of corrugated tube by using software and convective Heat transfer coefficient (HTC) of plain tube is compared with corrugated tube. Maximum convective HTC was observed for heat exchanger. This paper mainly focuses on improving the heat transfer capability in a shell and tube heat exchanger by varying tubes geometry. Study carried out on the design of the heat exchanger and by increasing overall HTC to prove more heat transfer is possible.

Keywords: *Heat Transfer Rate, Corrugated Tube, CFD, Heat Transfer Coefficient*

1. INTRODUCTION

A heat exchanger is a heat transfer device to provide heat transfer thermal energy between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid available, at different temperatures. In most of heat exchanger available, the fluids separated by a heat transfer surface, and in which they ideally do not mix.

The shell-and-tube heat exchangers [STHE] are still the most common type in use. They have larger heat transfer surface area-to-volume ratios than the most of common types of heat exchangers, and they are manufactured easily for a large variety of sizes and flow configurations. They can operate at high pressures, and their construction facilitates disassembly for periodic maintenance and cleaning. The shell-and-tube heat exchangers consist of a bundle of tubes enclosed within a cylindrical shell. One fluid flows through the tubes and a second fluid flows within the space between the tubes and the shell. Geometry is one of the parameter which affects the performance of heat exchanger. As its name implies, this type of heat exchanger consists of a shell (a large pressure vessel) with a bundle of tubes inside it. One fluid runs through the tubes, and another fluid flows over the tubes (through the shell) to transfer heat between the two fluids. Shell-and-tube exchangers are designed and fabricated according to the standards of the Tubular Exchanger Manufacturers Association (TEMA)

1.1 Components of STHE:

It is essential for the designer to have a good working knowledge of the mechanical features of STHEs and how they influence thermal design. The principal components of an STHE are:

- Shell;
- shell cover;
- Tubes;
- Channel;
- channel cover;
- Tube sheet

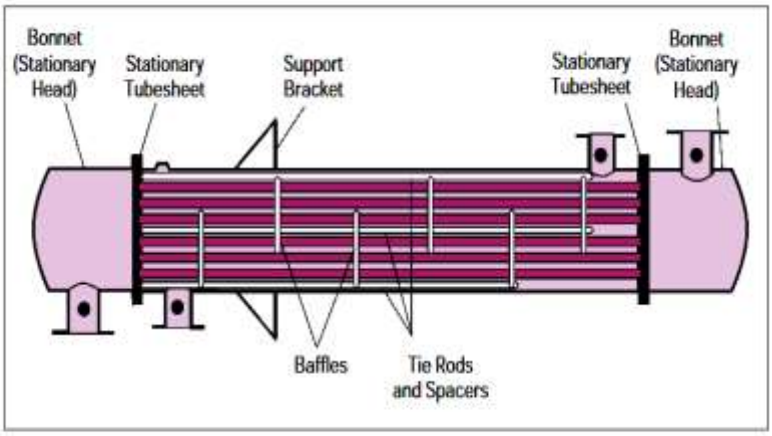

Fig.1.1: A schematic diagram of STHE

1.2 Application:

1) As action heat exchangers in the petroleum-refining and chemical industries.
2) As steam generator, condensers, boiler feed water heater, and oil coolers in power plant.
3) In some air-conditioning and refrigeration as condenser and evaporators.
4) In waste heat recovery applications with heat recovery from liquids and more dense fluids.
5) In environmental control

1.3 Heat Transfer Enhancement Techniques

Heat transfer enhancement is one of the fastest growing areas of heat transfer technology. The technologies are classified into active and passive techniques depending on how the heat transfer performance is improved. A corrugated is a typical passive technique that uses a specific geometry to induce swirl on the tube side flow. The twisted tube heat exchanger consists of a bundle of uniquely formed tubes assembled in a bundle without the use of baffles. Twisted tube technology provide highest heat transfer coefficient possible in tubular heat exchanger. In uniform shell side flow the complex interrupted swirl flow on shell side maximizes turbulence while minimizing pressure drop. The tube ends are round to allow conventional tube to tube sheet joints. Swirl flow in tube creates turbulence to improve heat transfer. By keeping the flow turbulent one secures a high heat transfer performance.

1.4 Why was Corrugated Tubes Developed?

- To have efficient heat transfer even in liquids with high viscosity, liquids with large fibres or particulates
- To increase tube side heat transfer coefficients, with minimum increase in pressure loss.
- To overcome disadvantages of other methods of artificial enhancing the heat transfer coefficient, viz., increased resistance to fluid flow – increased pressure loss. Unpredictable characteristics difficult to design / manufacture / replace / service. Difficult to clean. Low running reliability

2. LITERATURE REVIEW

Prince Serrao, et al Numerical analysis on plain and corrugated pipes has been performed using ANSYS FLUENT. It is observed that there is an average increase in overall heat transfer coefficient of 54.67%. We can see that percentage increase in overall heat transfer coefficient almost becomes independent of flow rate, as it remains in the range of 50-60%. The equivalent size of corrugated pipe for same flow rate of 0.0969 kg/s is 0.407 m for length of plain pipe as 1.5 m to achieve same outlet temperature. Hence there is a decrease of almost 70% in length of corrugated pipe. Since pressure drop for corrugated pipe is twice than that of plain pipe for mass flow rate of 0.0969 kg/s, hence pumping power required is double than that of plain pipe. Hence, there is an increase in 50% of pumping power for corrugated pipe.

Apu Roy, D.H.Das has been carried out with a view to predicting the performance of a shell and finned tube heat exchanger in the light of waste heat recovery application. The performance of the heat exchanger has been evaluated by using the CFD package fluent and the available values are compared with experimental values. By considering different heat transfer fluids the performance of the above heat exchanger can also be predict. The performance parameters of heat exchanger such as effectiveness, overall heat transfer coefficient, energy extraction rate .

Chintan D Patel, Prashant Sharmaand Amitesh Paul applied Taguchi method to perform screening of experiments and to identify the important significant parameters which are affecting the efficiency of shell and tube type heat exchanger. The prefix parameters (tube diameter, mass flow rate and pitch length) are used as input variable and the output parameter is maximum temperature difference of shell and tube heat exchanger. Nine different models are made in Solid Works 2012 software and CFX analysis is carried out in ANSYS 12.0. The Minitab 16 software is used for Taguchi analysis. Result obtained from the Taguchi analysis shows that which combination of design parameter gives the minimum outlet temperature of water..

Alok Vyas, Prashant Sharma discussed about tubular heat exchanger there are several thermal design factors that are to be taken into account when designing the tubes in the tubular heat exchangers. They are tube diameter, tube length, number of tubes, number of baffles & baffles inclination etc. The characteristics of flow and heat transfer within the shell are not simple. This paper conducted various experimental analyses to predict the characteristics of difference in temperature and pressure drop, which are the performances of heat exchanger. In this study, the diameter of tube, the number of tubes and the number of baffles are considered as the design factors. Also, factors that affect the performances of heat exchanger were selected through design of experiment procedures. The purpose of this paper is how to improve the performance of tubular heat exchangers

Swapnaneel Sarma, D.H.Das has been carried out with a view to predicting the performance of a shell and finned tube heat exchanger in the light of waste heat recovery application. The performance of the heat exchanger has been evaluated by using the CFD package fluent 6.3.26 and has been compared with the existing experimental values. An attempt has also been made to calculate the performance of the above heat exchanger by considering triangular fins instead of regular rectangular fins and the result so obtained have been compared. The performance parameters pertaining to heat exchanger such as effectiveness, overall heat transfer coefficient, energy extraction rate etc.

3. METHODOLOGY

3.1 Design Methodology

In the present project, the methodology used in the design of the heat exchanger is thermal design. Thermal design of a shell and tube heat exchanger typically includes the determination of heat transfer area, number of tubes, tube length and diameter, tube layout, number of shell and tube passes, type of heat exchanger (fixed tube sheet, removable tube bundle etc), tube pitch, number of baffles, its type and size, shell and tube side pressure drop and heat transfer coefficients.

3.2 CFD Methodology

CFD may be used to determine the performance of a component at the design stage, or it can be used to analyses difficulties with an existing component and lead to its improved design. For example, the pressure drop through a component may be considered excessive: The first step is to identify the region of interest
The process of performing a single CFD simulation is split into four components:

1. Geometry
2. Meshing
3. Physics Definition/Pre Processing
4. Solver
5. Post-processor

3.3 Experimentation and data collection of STHE

A shell and tube heat exchanger is placed in between vacuum pump and curing and moulding machine to reduce the temperature of gas before passing through the pump. The plain tube shell and tube heat exchanger is used in this industry as a transfer heat from the curing and moulding machine. In Company used a flue gas for curing and moulding process of tyres. Curing is the process of applying pressure to the green tire in a mould in order to give it final shape and applying heat energy to stimulate the chemical reaction between the rubber and other materials.

Data collected by Experimentation on STHE

Specification:

Hot Fluid: Flue Gases
Cold Fluid: Water
Type of Tubes: Plain Tubes
Number of Tubes: 5
Shell Material = Steel

Tube Material = Copper

Dimensions:

Parameters	Values
Heat exchanger length	495mm
Inner diameter of shell	200mm
Outer diameter of tube	23 mm
Inner diameter of Tube	19 mm
Number of tubes	5
Number of baffles	3

Experiment Reading:

$T_{hi} = 180^0C$
$T_{ci}= 28^0C$
$T_{ho} = 165^0C$
$T_{co} = 32^0C$

Volume flow Rate of Flue Gas from the curing plant = 300 m^3/Hr

To Find the

Mass Flow Rate of Flue Gas

$m_h=300\times 0.788/3600$
$m_h=0.0656 kg/sec$

Mass Flow Rate of Cold Fluid

$Q = m_hC_{ph}\ (\Delta T)_h = m_cC_{pc}(\Delta T)_c$
$Q=m_hC_{ph}\ (T_{hi}-T_{ho}) = m_cC_{pc}(T_{co}-T_{ci})$
$0.656\times1.092\times (180-165) = m_c\times4.178\times(32-28)$
$\therefore m_c= 0.641$ kg / sec

Properties of Fluids:

Hot Fluid (Flue Gas)

$\rho_h = 0.788$ kg/m^3
$C_{ph} = 1.092$ KJ/Kgk
$\mu_h = 23.80 \times 10^{-6}$ kg/ms
Pr = 0.671
K_h =0 .03714 w/ mk

Cold Fluid (Water)

$\rho_c= 998$ kg/m^3
$C_{pc}= 4.178$ kg / kgk
$\mu_c = 7.09 \text{ X } 10^{-4}$ kg/ms
Pr = 5.650
$K_c = 0.6178$ w/ mk

3.4 Modelling and Meshing of the Shell and tube Heat Exchanger:

Modelling is done using Design Modeller provided in ANSYS Fluent. Initially a relatively coarser mesh is generated with 1.8 Million cells. This mesh contains mixed cells (Tetra and Hexahedral cells) having both triangular and quadrilateral faces at the boundaries.

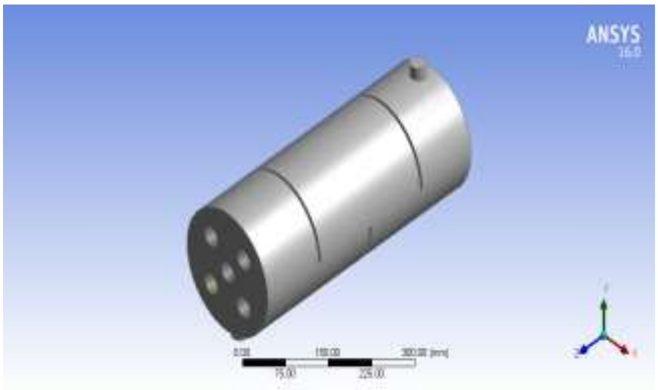

Fig.3.1: Modelling of plain tube

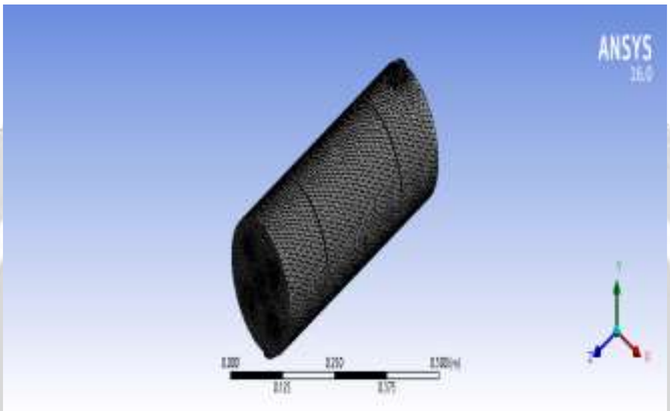

Fig.3.2: Meshing of plain tube

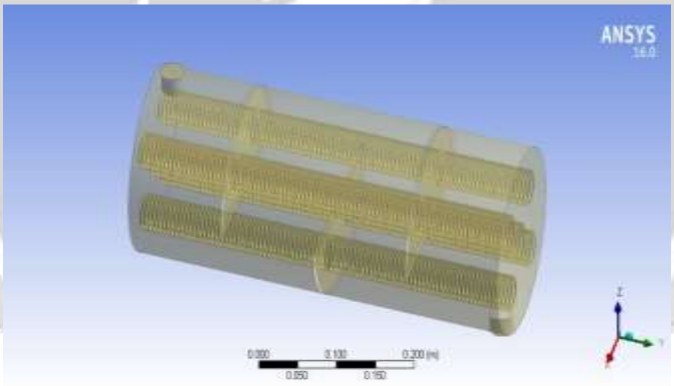

Fig.3.1: Modelling of corrugated tube

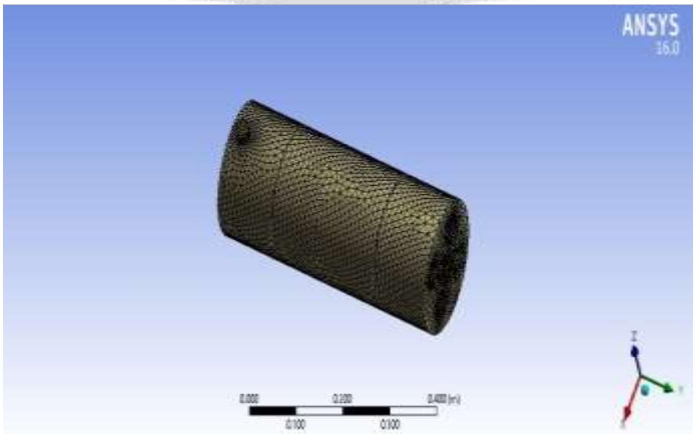

Fig.3.4: Meshing of Corrugated Tube

4. RESULT AND DISCUSSION

4.1 Variation of Temperature for plain tube:

The temperature distribution of shell along the length is examine and from Image 5.3 temperature distribution of tube is examine. From Image 5.4 profile is examined to understand the flow distribution across the cross section at different positions in heat exchanger.

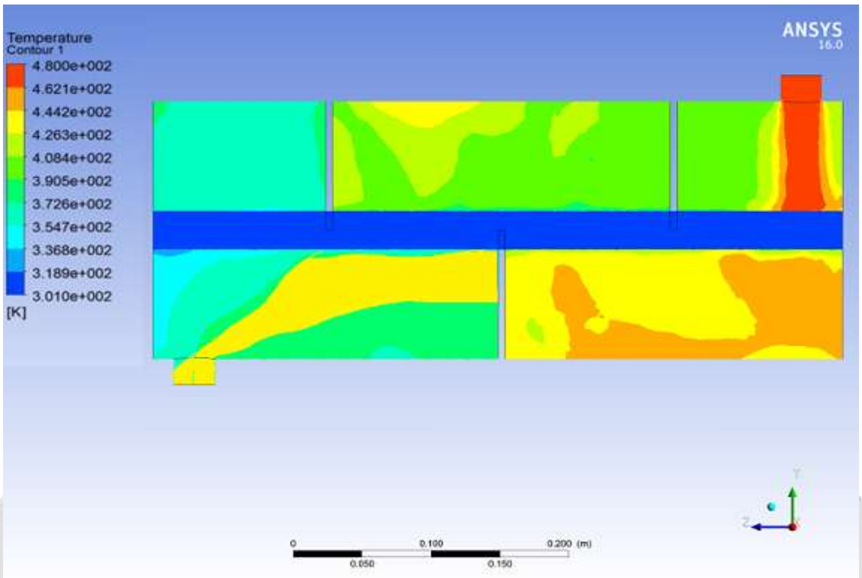

Fig.4.1: Variation of Temperature for plain tube

4.2 Variation of Temperature for corrugated tube:

The profile is examined to understand the flow distribution across the cross section at different positions of the shell and tube in heat exchanger.

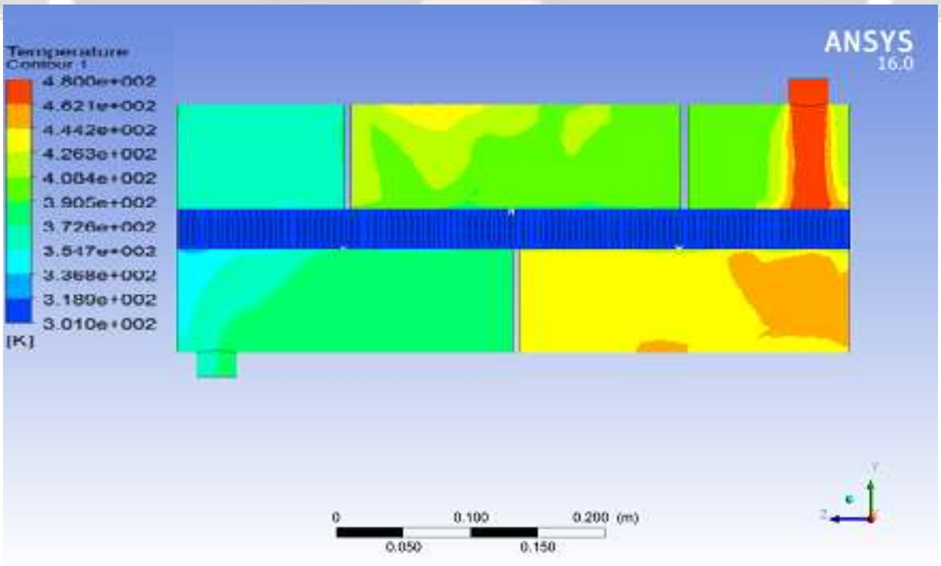

Fig.4.2: Variation of Temperature for corrugated tube

4.3 Result and Comparison of simulation parameters of corrugated tube and plain tube:

Parameter	Numerical (Corrugated Tube)	Numerical (Plain Tube)	Difference	Remark
Hot Fluid Inlet Temperature (K)	453	453	0	-
Hot Fluid Outlet Temperature (K)	424.65	436.27	11.62	Cooling of Flue Gas Increase
Cold Water Inlet Temp	301	301	0	-
Cold Water Outlet Temperature (K)	304.2	303.85	0.35	Heating of Cold Water Decreased
HTC of shell side (W/m^2K)	166.15	151.1	15.15	HTC on shell side is large as compare to Tube side
HTC of tube side(W/m^2K)	27.56	26.35	1.21	
Overall Heat Transfer Coefficient (W/m^2K)	20.07	19.02	1.05	Overall heat transfer coefficient increased

Above table shows that the numerical results of the parameters obtained from the CFD analysis on corrugated and plain tube STHE. From table the graph is plot. The Graph shows that the cooling of flue gasses is increased. The HTC on shell side is large as compared to the tube side in corrugated tube. The convective HTC on shell side is increased by 15.15 % in corrugate tube as compared to plain tube.

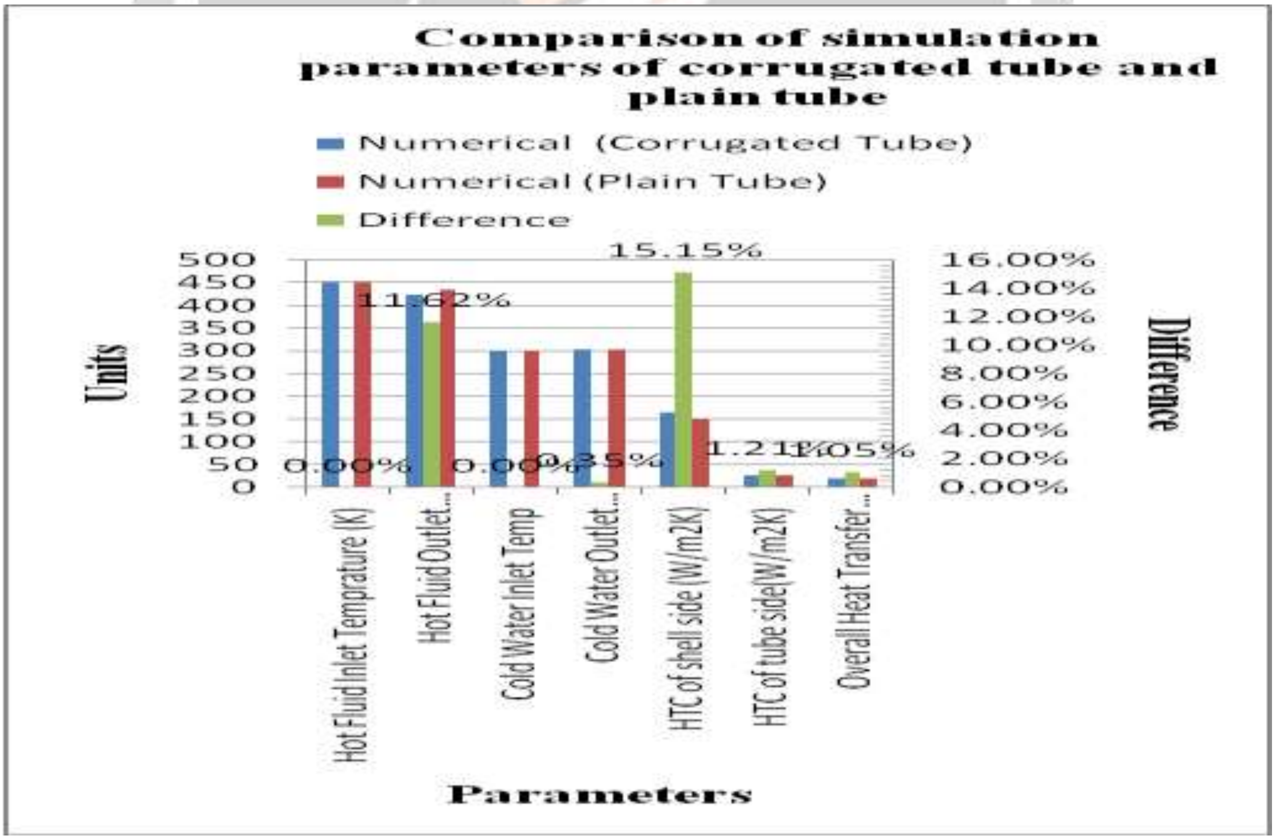

Fig.4.3: Graph showing Difference of simulated parameters in corrugated tube and plain tube

5. CONCLUSION

Shell and tube heat exchanger is designed to analyse the effect of variation of tube geometry on the heat transfer rate, heat transfer coefficient and Overall heat transfer coefficient. The result of simulation and experiment shows that the heat transfer coefficient on the shell side is much higher in case of corrugated tube than the plain tube. The HTC is obtained in corrugated tube 15.15 % higher than the plain tube.

6. FUTURE SCOPE

Corrugated pipe heat transfer is a very promising area of research and experimentation and more advanced modifications, such as spiral and different types of corrugations could be produced to achieve much higher levels of heat transfer. The pitch can be varied to see the variation in results. By altering certain parameters such as corrugation size, heating capacity and pumping power, this setup can also be used for industrial applications. The working fluid can be taken as non-Newtonian fluids and Nano fluids.

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