Heat Transfer Augmentation in a Double Pipe Heat Exchanger Using Coil Insert

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***Abstract*- In present study, heat transfer and turbulent flow of water/alumina nanofluid in a counter flow double pipe heat exchanger have been investigated. The governing equations have been solved using CFD simulation, based on finite volume method. Single-phase and standard k-e models have been used for nanofluid and turbulent modeling, respectively. The internal fluid has been considered as hot fluid (nanofluid) and the external fluid, cold fluid (base fluid). The effects of flow direction and Reynolds number on base fluid, nanofluid and wall temperatures, and Nusselt number and convection heat transfer coefficient have been studied. The results indicated that increasing the Reynolds number causes enhancement of Nusselt number and convection heat transfer coefficient. In this study geometrical model is generated in the design modular in ANSYS 14.5 and the designed model is meshed in the ICEM CFD. Applying the desired boundary condition the meshed model has imported for CFD simulation and the results are analysed. Therefore, using of counter flow heat exchangers is recommended in higher Reynolds numbers.**

Index Terms- ANSYS 14.5, Nusselt number, Reynolds Number, Heat transfer, CFD, Mesh.

I. INTRODUCTION

Heat exchanger is a device facilitating heat transfer between two or more fluids. It is extensively used in many industries like thermal power plants, chemical processing, air conditioning equipment and refrigerators. Heat exchangers have been classified in many different ways.

Heat exchangers have different applications ranging from conversion, recovery of thermal energy in different industrial, domestic and commercial uses. Some public examples include cooling in thermal processing of chemical, condensation in power, agricultural products, pharmaceutical, steam generation, sensible heating, cogeneration plants, waste heat recovery and fluid heating in manufacturing. Enhance in heat exchanger's performance can make more economical design of heat exchanger which can aid to make energy, material and cost savings related to a heat exchange process.

1.1 Heat Transfer Enhancement

Heat transfer enhancement is a process of increasing the heat transfer rate and thermo hydraulic performance of a system using various methods. The methods of heat transfer enhancement are employed for developing the heat transfer without affecting the overall realization of the systems significantly, and it covers a wide range of areas where heat exchangers are used for such functions as air-conditioning, refrigeration, central heating systems, cooling automotive components, and many uses in the chemical industry.

Heat transfer enhancement methods exist on three general classifications which are passive, active, and compound techniques. Active methods require external power to input the process; in contrast, passive methods do not require any additional energy to improve the thermo hydraulic performance of the system. Also, two or more passive and active techniques can be used together and that is called compound technique, which is employed to produce a higher augmentation than using one passive or active technique independently.

II. LITERATURE REVIEW

Broad reviews of research in the field of heat exchanger spatially on double pipe heat exchanger are shown below:

Xue Chen, Chuang Sun et.al 2019 A numerical investigation is performed to analyse the high-temperature heat transfer behaviour in a double-pipe heat exchanger filled with open-cell porous foam. The Forchheimer-extended Darcy equation and the local thermal non equilibrium model are utilized to simulate the flow and thermal transport inside the foam regions, considering the coupling effects between the inner and annular spaces. The effect of solid wall thickness is incorporated in the modelling process, following the continuity conditions of temperature and heat flux at the porous-solid interface.

Qianmei Fu, Jing Ding et.al, 2019 in this study the effect of structure ratio of heat exchanger and the entrance velocity of S-CO2 on heat transfer and flow resistance are investigated numerically.

A.M. Ali, El-Maghlany, 2018 three dimensional, steady sate and incompressible CFD model was constructed for investigation of the effect of rotation and eccentricity on the heat transfer rate. A double pipe heat exchanger which was used for this study consists of an inner pipe and an outer pipe of diameter 50 mm and 150 mm respectively with a length of 2000 mm.

Mohamad Omidi, Farhadi, 2017 Growing need to develop and improve the effectiveness of heat exchangers has led to a broad range of investigations for increasing heat transfer rate along with decreasing the size and cost of the industrial apparatus accordingly. One of these many apparatus which are used in different industries is double pipe heat exchanger.

Mohammad Hussein Bahmani, 2017 In present study, heat transfer and turbulent flow of water/alumina nanofluid in a parallel as well as counter flow double pipe heat exchanger have been investigated. The governing equations have been solved using an in-house FORTRAN code, based on finite volume method. Single-phase and standard k-e models have been used for nanofluid and turbulent modeling, respectively.

M. Sheikholeslami, D.D. Ganji, 2016 Effect of typical and perforated conical ring turbulators on hydrothermal behavior of air to water double pipe heat exchanger is investigated. Two arrays (Direct conical ring (DCR) array and Reverse conical ring (RCR) array) are considered. Experimental analysis is examined for different values of open area ratio (0–0.0833), Reynolds number (6000–12,000), conical angle (0°–30°) and pitch ratio Mohammad Hussein Bahmani, Ghanbarali Sheikhzadeh (1.83–5.83). Correlations for friction factor, Nusselt number and thermal performance factor are presented.

Hamed Sadighi Dizaji, Samad Jafarmadar et.al 2015 Heat transfer, pressure drop and effectiveness in a double pipe heat exchanger made of corrugated outer and inner tubes have been experimentally investigated in this paper. Both of the inner and outer tubes were corrugated by means of a special machine. New various arrangements of convex and concave corrugated tube were investigated. Heat transfer coefficient was determined using Wilson plots.

H.J. Xu, Z.G. Qu 2014 The self-coupling heat transfer in a counter-flow double-pipe heat exchanger filled with metallic foams is numerically investigated. The Forchheimer extended Darcy equation with a quadratic term is adopted for the momentum equation, whereas the local thermal non-equilibrium model is applied for establishing energy equations with thermal dispersion.

N. Targui, H. Kahalerras 2013 A numerical investigation is carried out to analyse the effect of porous baffles and flow pulsation on a double pipe heat exchanger performance. The hot fluid flows in the inner cylinder, whereas the cold fluid circulates in the annular gap. The Darcy–Brinkman–Forchheimer model is adopted to describe the flow in the porous regions and the finite volume method is used to solve the governing equations with the appropriate boundary conditions.

III. RESEARCH OBJECTIVES

The design of heat exchangers has been facing problems due to lack of experimental data available regarding the behaviour of the fluid in coils .Enhancing heat transfer always remains the area of special interest so that much effective heat exchangers could be designed. In this study the objective is to evaluate the following aspects using ANSYS 14.5 simulation

- To develop model of double pipe heat exchanger with coil insert.
- Validation will be carried on CFD model with comparison of previous experimental model.
- Compare the heat transfer rate (Nu) with respect to plane tube.
- Compare the friction losses or pressure drop with respect to plane tube.

- Find out the enhancement efficiency.

IV. METHODOLOGY

The geometry of double pipe heat exchanger performing the simulation study is taken form one of the research scholar's Mohammad Hussein Bahmani et al. (2017) paper with exact dimension. The part of model was designed in ANSYS (Fluent) workbench14.5 software. The geometric dimension of the double pipe counter flow heat exchanger is shown in the Table.

Table 1: Geometric Dimension of Heat exchanger

Dimension				
Pipe thickness	Inner tube dia.	Outer tube dia.	Wire dia.	Length
2mm steel	26 mm	50	2mm	2m

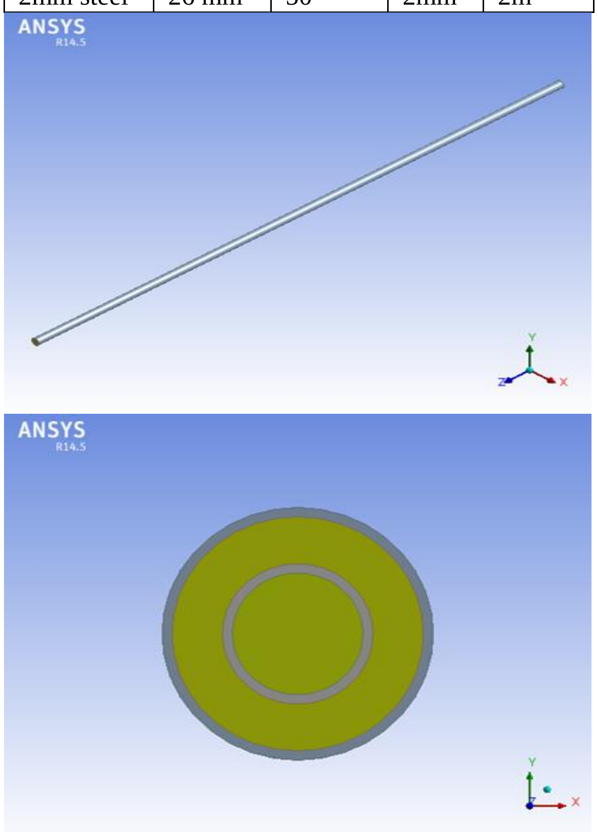


Figure 1 Geometry of heat exchanger without coil.

Meshing: By using ANSYS software in meshing edge sizing has been done. Inflation also makes for proper contact mesh. Mesh contains mixed cells per unit area (ICEM Tetrahedral cells) having meshing type tetrahedral and quadrilateral at the boundaries.

Table 2: Meshing details

Meshing Detail			
	Meshing type	No. of nodes	No. of elements
Without coil	quad core tetrahedral	1180836	796308
With coil	quad core tetrahedral	1450540	1296716

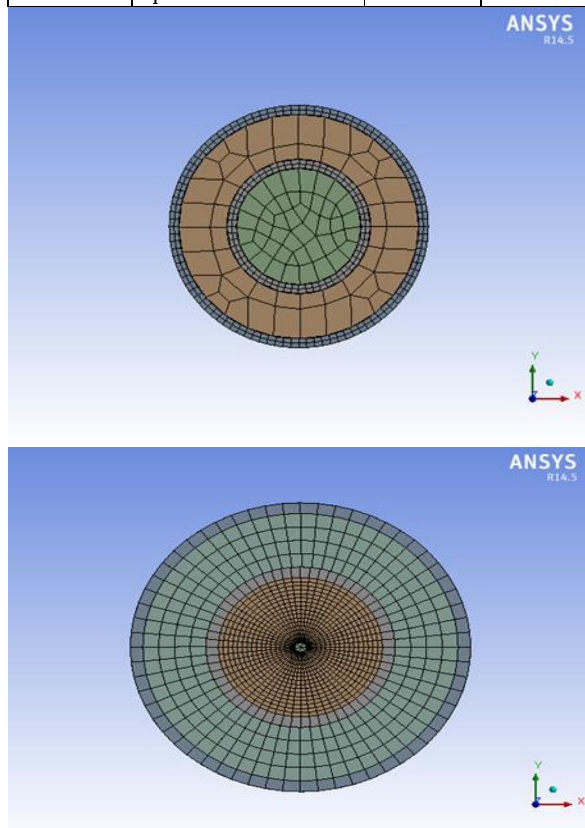
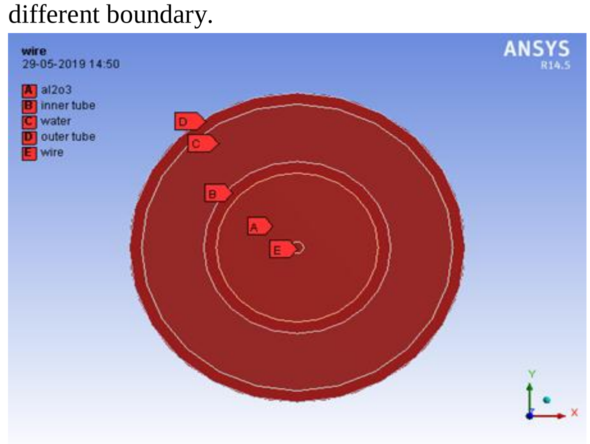


Figure 2 meshing of heat exchanger without coil and with coil insert.

Boundary condition: A different part of the heat exchanger and fluid flowing inside the heat exchanger is selected and the names are given to them so that boundary conditions can be applied on different boundary.



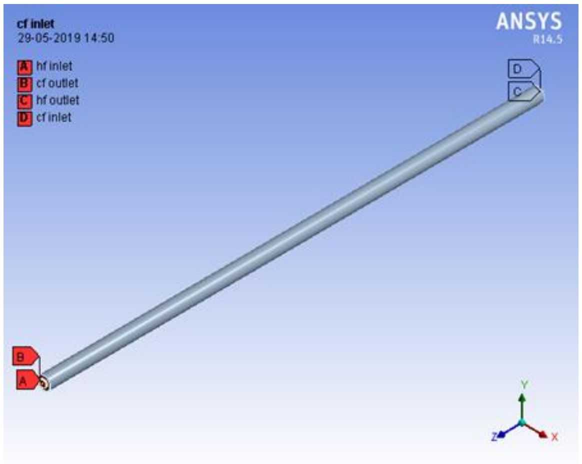


Figure 3 Name selections of heat exchanger fluid inlet and outlet with coil insert.

V. RESULTS AND DICUSIONS

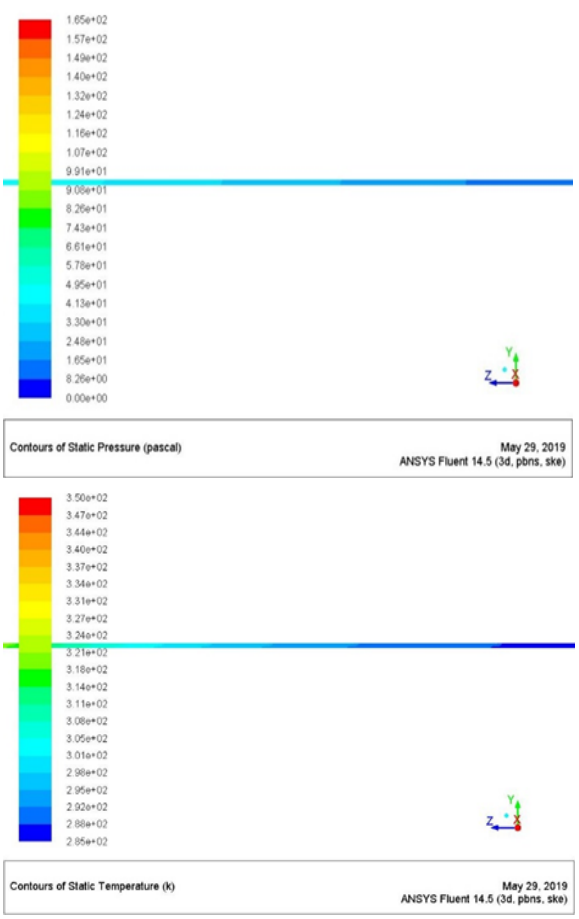


Figure 4. Pressure contour & Temperature contour at Re=10,000 without coil.

Table 2 Shows the value of Nusselt number (Nu) of Reynolds number=10,000.

Reynolds number	Nu of water from mathematical modeling	Nu of water from Base paper	Error Percentage (%)
10,000	13.21	13	1.58

Table 3 Results without coil insert

Reynol d's no.	Heat transfer coefficient(W/m^2-K)		Velocity (m/s)		Outlet Temp.(K)		Nusselt no.
	Inner side	Outer side	Inner side	Outer side	Inner side	Outer side	
10000	998.27	999.35	0.1787	0.059	291.56	286.33	13.21

After validating the CFD model of heat exchanger, we then used the heat exchanger having coil outside the inner tube. Coil is mainly used to increase the turbulence inside the heat exchanger.

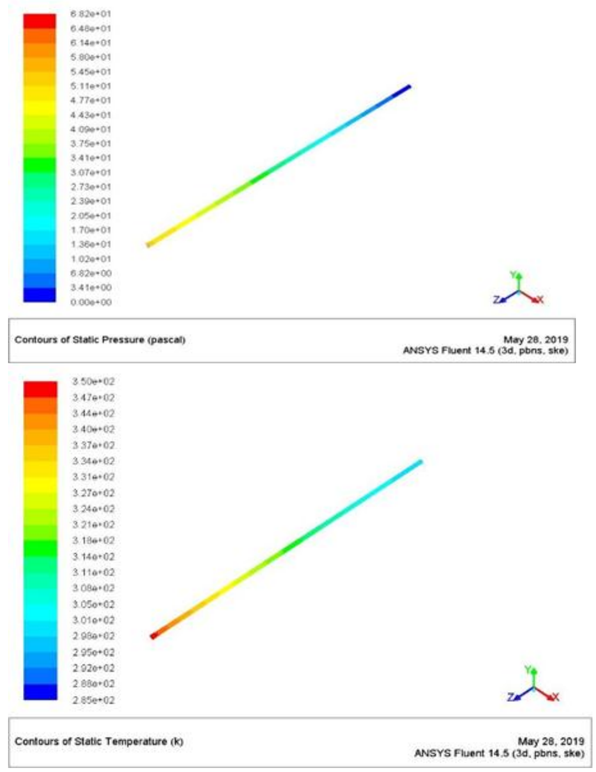
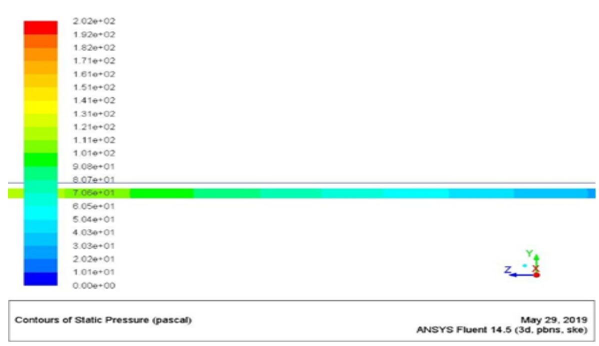


Figure 5 Pressure contour & Temperature contour at Re=10,000 with coil insert.



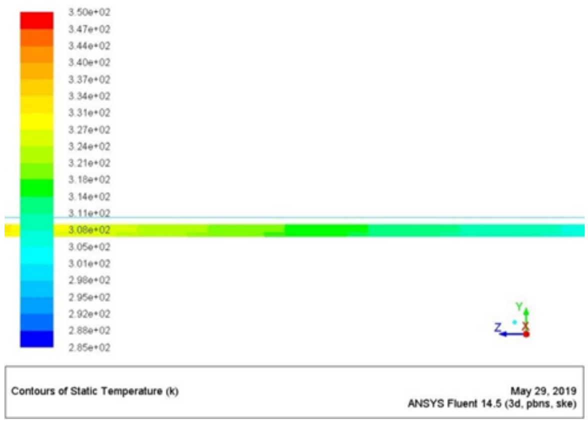
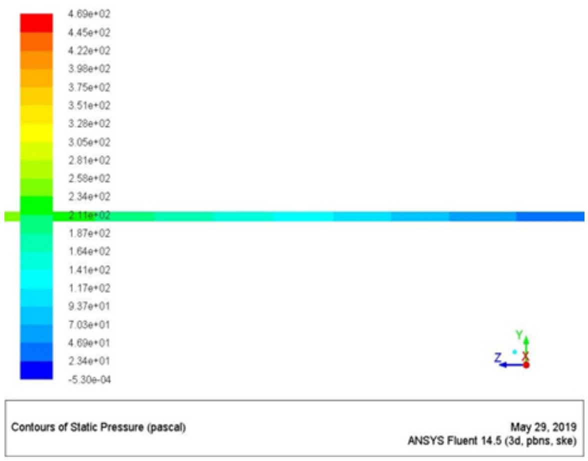


Figure 6 Pressure contour & Temperature contour at Re=20,000 with coil insert.



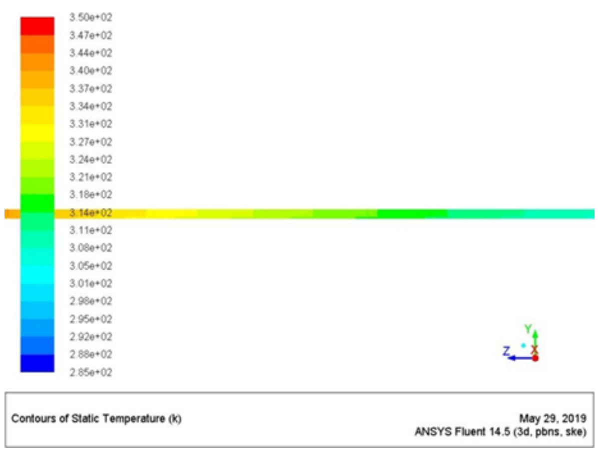


Figure 7 Pressure contour & Temperature contour at Re=30,000 with coil insert.

Table 4 Results with wire insert

Result with wire insert							
Reynold's no.	Heat transfer coefficient(W/m^2-K)		Velocity (m/s)		Outlet Temp.(K)		Nusselt no.
	Inner side	Outer side	Inner side	Outer side	Inner side	Outer side	
10000	1089	1088.	0.1	0.059	294.	298.	26.61

	.01	99	787		03	19	036
20000	1744 .35	1906. 36	0.3 574	0.118 2	292. 95	303. 829	47.98 78
30000	2659 .47	2669. 7212	0.5 361	0.177 291	292. 283	307. 358	68.48 62

VI. CONCLUSIONS

In this analysis, the cumulative effect of inserting coil in double pipe heat exchanger has been investigated using CFD analysis. Based on the results, obtained by the CFD and mathematical calculations it is found that; In order to validate the study, the dimensions of previous setup given in base paper were modeled and analysis is carried out. It is observed that between previous and present simulation results the variation is less than 2%. The slop of convection heat transfer coefficient and Nusselt number diagrams are almost constant. The difference in temperature at the outlet of heat exchanger for Re=10,000 is 4.14 K, for Re= 20,000 is 10.879 and for Re= 30,000 is 15.075 K. It means as the Reynold's no. increases the rate of heat transfer increases, greater the temperature difference grater the heat transfer. At Re=10,000 the Nusselt no. without coil insert is 13.21 and with coil insert is 26.61. Overall heat transfer coefficient is increased by 15% by using coil insert.

REFRENCES

[1] Xue Chen, Chuang Sun "Conjugated heat transfer analysis of a foam filled double-pipe heat exchanger for high-temperature application." International Journal of Heat and Mass Transfer 134 (2019) 1003–1013

[2] Quanmei Fu, Jing Ding "Numerical simulation of heat transfer performance between molten salt and supercritical CO2 in double pipe heat exchanger." Energy Precedia 158 (2019)n5741-5746

[3] Marwa A.M. Ali, Wael M. El-Maghlany "Heat transfer enhancement of double pipe heat exchanger using rotating of variable eccentricity inner pipe" Alexandria Engineering Journal (2018) 57, 3709–3725

[4] Mohamad Omidi, Mousa Farhadi "A comprehensive review on double pipe heat exchangers." Applied Thermal Engineering 110 (2017) 1075–1090

[5] Mohammad Hussein Bahmani, Ghanbarali Sheikhzadeh "Investigation of turbulent heat transfer and nanofluid flow in a double pipe heat exchanger." Advanced Powder Technology (2017)

[6] Zhan Liu, Yanzhong Li "Thermal analysis of double-pipe heat exchanger in thermodynamic vent system" Energy Conversion and Management 126 (2016) 837–849

[7] Ali Shakiba, Khodadad Vahedi "Numerical analysis of magnetic field effects on hydro-thermal behavior of a magnetic nanofluid in a double pipe heat exchanger. Journal of Magnetism and Magnetic Materials." 11 November 2015

[8] Hamed Sadighi Dizaji, Samad Jafarmadar "Experimental studies on heat transfer and pressure drop characteristics for new arrangements of corrugated tubes in a double pipe heat exchanger." International Journal of Thermal Sciences 96 (2015) 211e220

[9] Mohsen Sheikholeslami M. Jafaryar. "Thermal management of double pipe air to water heat Exchanger." Energy and Buildings (2014)

[10] Husam A. Hasan, M.A. Wahid "Heat transfer enhancement of nanofluids in a double pipe heat exchanger with louvered strip inserts." International Communications in Heat and Mass Transfer (2013)

[11] N. Targui, H. Kahalerras "Analysis of a double pipe heat exchanger performance by use of porous baffles and pulsating flow" Energy Conversion and Management 76 (2013) 43–54

[12] Ingo Riehl, Ulrich Gross "Modelling of the borehole filling of double U-pipe heat exchangers" Geothermics 39 (2010) 270–276

[13] C.M. Astorga-Zaragoza, O. Herna "Bounded positive control for double-pipe heat exchangers" Control Engineering Practice 17 (2009) 136–145

[14] Nitin Aggarwal, Vijay Aggarwal "Optimum design of double pipe heat exchanger." International Journal of Heat and Mass Transfer 51 (2008) 2260–2266

[15] N. Targui, H. Kahalerras "Analysis of fluid flow and heat transfer in a double pipe heat exchanger with porous structures." Energy Conversion and Management 49 (2008) 3217–322

[16] J. Miriel, I. Colda "Mixed convection in a vertical double pipe heat exchanger" International Journal of Thermal Sciences 46 (2007) 540–550