2-D Modeling of Underground Coal Gasification (UCG)

S. Srikantiah[1], S. Mahajani[1], G. Samdani[1], A. Ganesh[1], P. Aghalayam[2]

1 Department of Chemical Engineering, Indian Institute of Technology Bombay, Mumbai, India
2 Indian Institute of Technology Madras, Chennai, India

INTRODUCTION

- Underground coal gasification (UCG) is a process which converts coal to syn gas at the underground coal seam itself. This process involves injection of reactive gases to the coal seam and bringing the product gases to the surface through a production well.
- UCG can help meet the rising energy demand by utilizing coal resources that otherwise would be too deep, or of poor quality, or simply not economical to mine. As UCG takes place, a cavity is formed underground in the coal seam which grows three-dimensionally.
- The growth of the cavity is affected by various factors such as flow field in the cavity, spalling of char/coal, temperature distribution in the cavity, etc. Because of complexity of the process, a simplified process model is needed to predict the performance of the UCG. This work presents one such model.

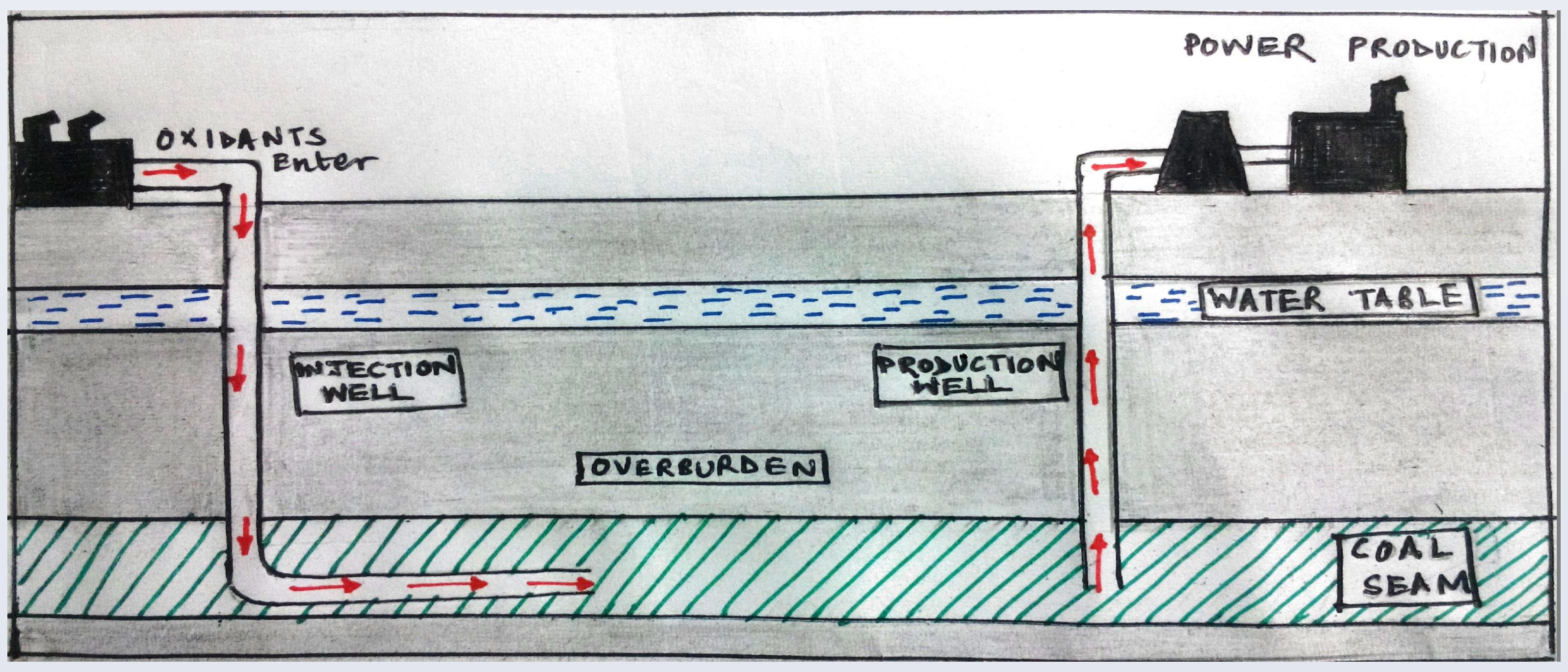

Figure 1. Schematic of the UCG process

OBJECTIVE

The objective of this work is to develop a two-dimensional model of the cavity to analyse its growth and product gas composition during the UCG process. The two-dimensional model is a reduced form of the actual three-dimensional cavity where the geometry for modeling is a vertical plane passing through the injection and production well.

COMPUTATIONAL METHOD

1) Solid Balance Equation-

$$\frac{\partial C_{Char}}{\partial t} = R_{Char}$$

2) Gas Balance Equation -

$$\frac{\partial C_i}{\partial t} + \nabla.(-D_i \nabla C_i) + u.\nabla C_i = R_i$$

3) Heat balance Equation -

$$(\rho C_p)_{eff}\frac{\partial T_s}{\partial t} + \nabla.(\rho_g u C_{p,g} T_s) = \nabla.\left(-k_{eff}\nabla T_s\right) + \sum_{i=1}^{3}(\Delta H_i * R_i)$$

(i) Transport in dilute species; (ii) Heat transfer in porous media; (iii) Brinkman's equation are solved in the Segregated Time Dependent Solver in COMSOL.

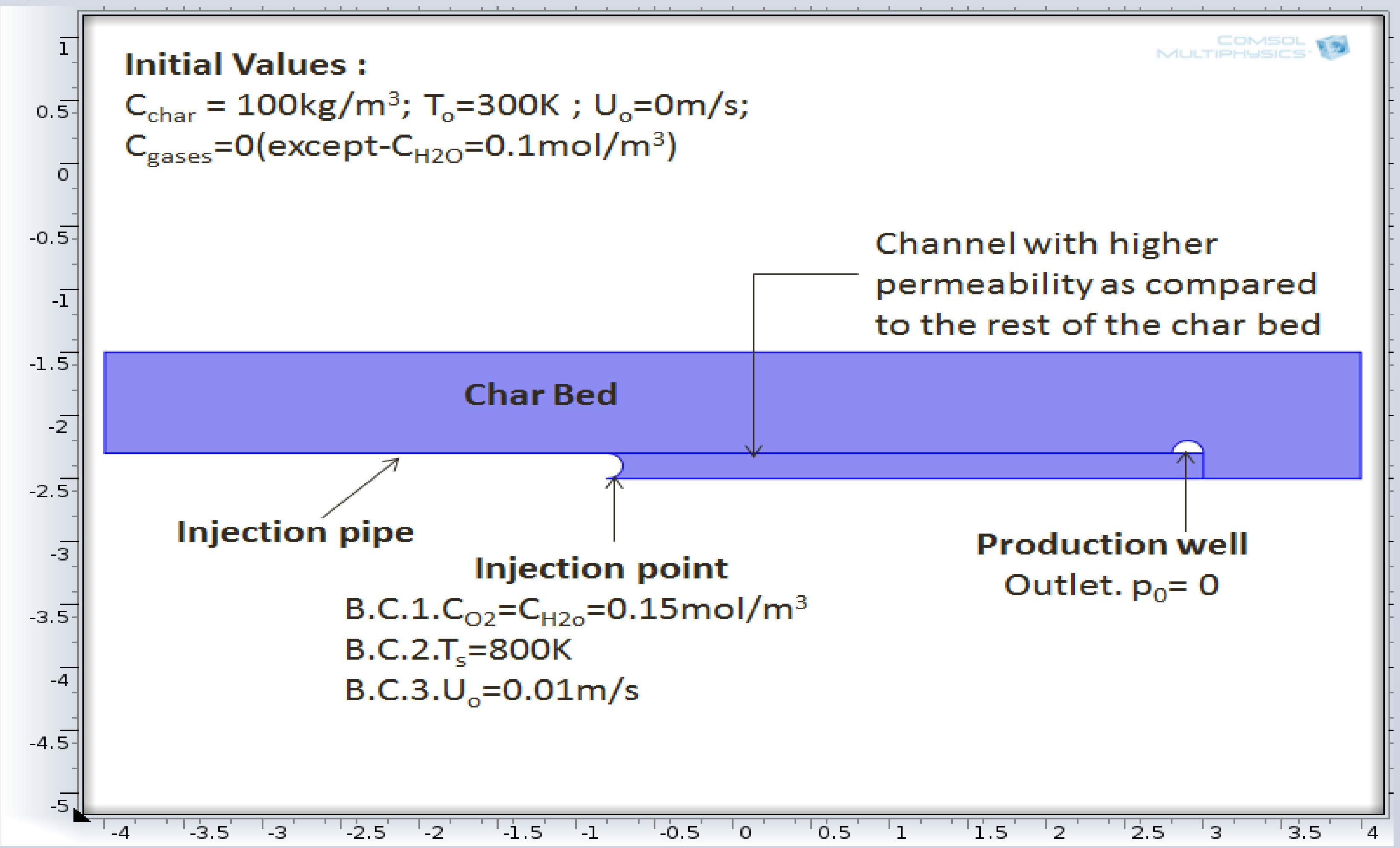

Figure 2. 2-D Geometry of the UCG process (COMSOL model)

RESULTS

Some of the representative results are shown in Fig.3, Fig.4 and Fig.5. The distribution of char density at time = 140 minutes is shown in Figure3 where it can be seen that the char near the inlet has been consumed till this time.

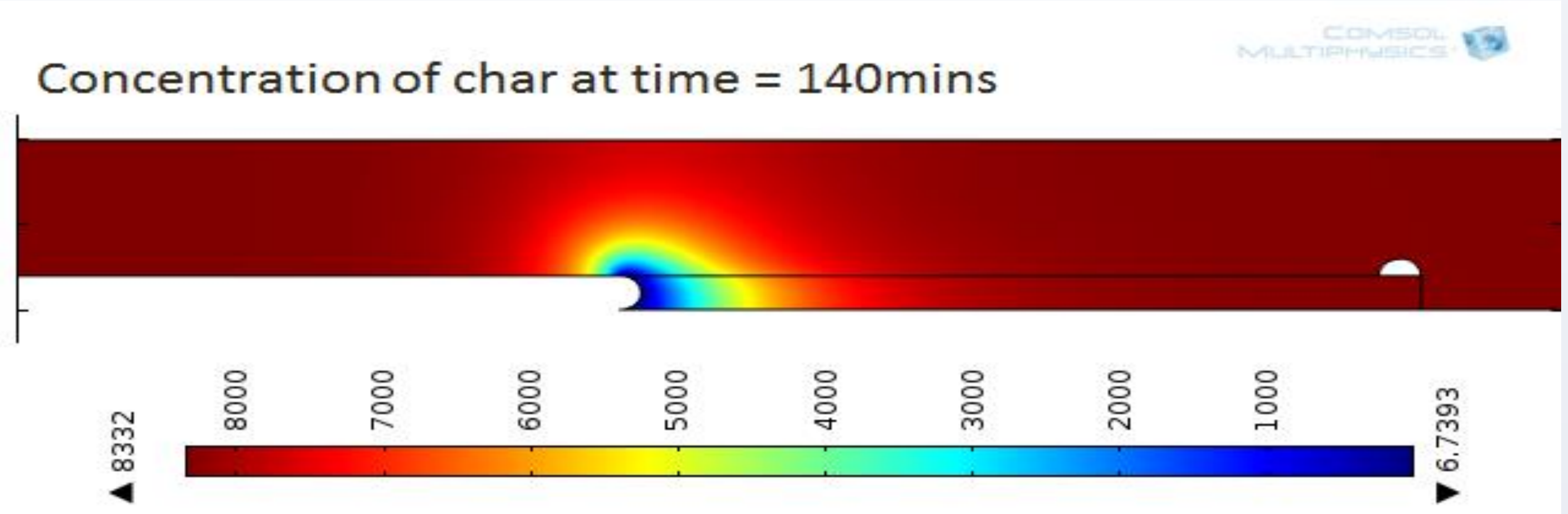

Figure 3. Concentration of char in the coal bed at time=140mins

As shown in Figure 4, oxygen concentration is very low at places away from the inlet as it gets consumed very fast due to the high rate of the combustion reaction. Carbon dioxide is generated from this combustion reaction and it gets consumed due to the gasification reaction. Hence, its concentration profile depends on the position of the reaction front of these two reactions. Figure 5 shows the profile of carbon dioxide where a maxima can be seen due to this very reason.

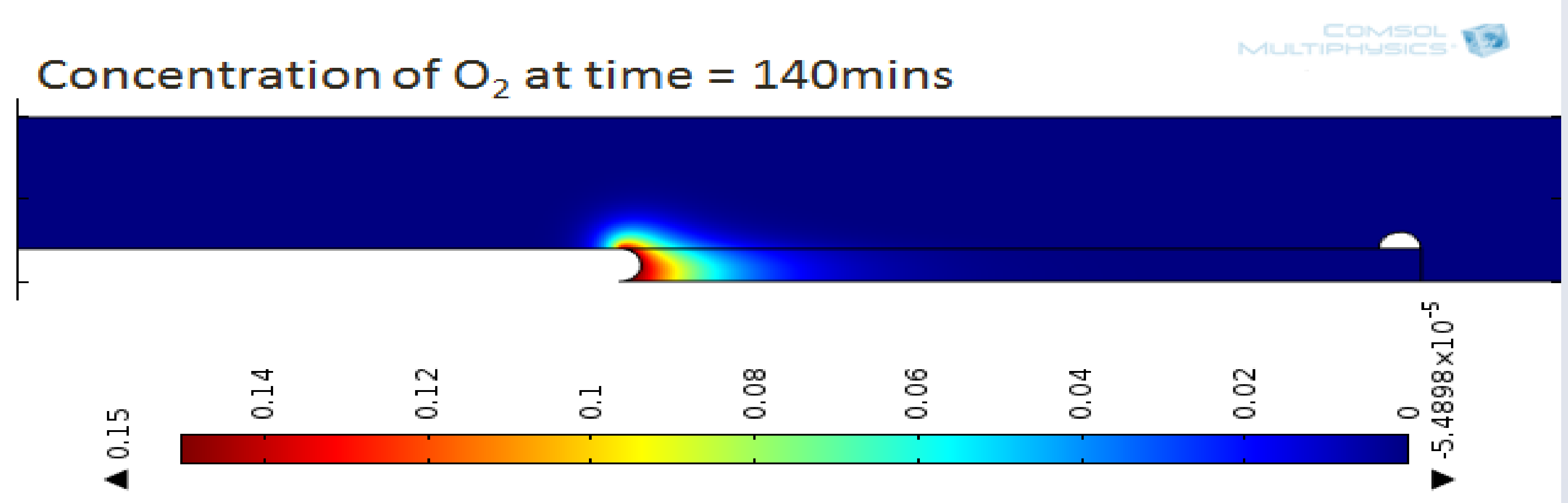

Figure 4. Concentration of oxygen(O_2) in the coal bed at time=140mins

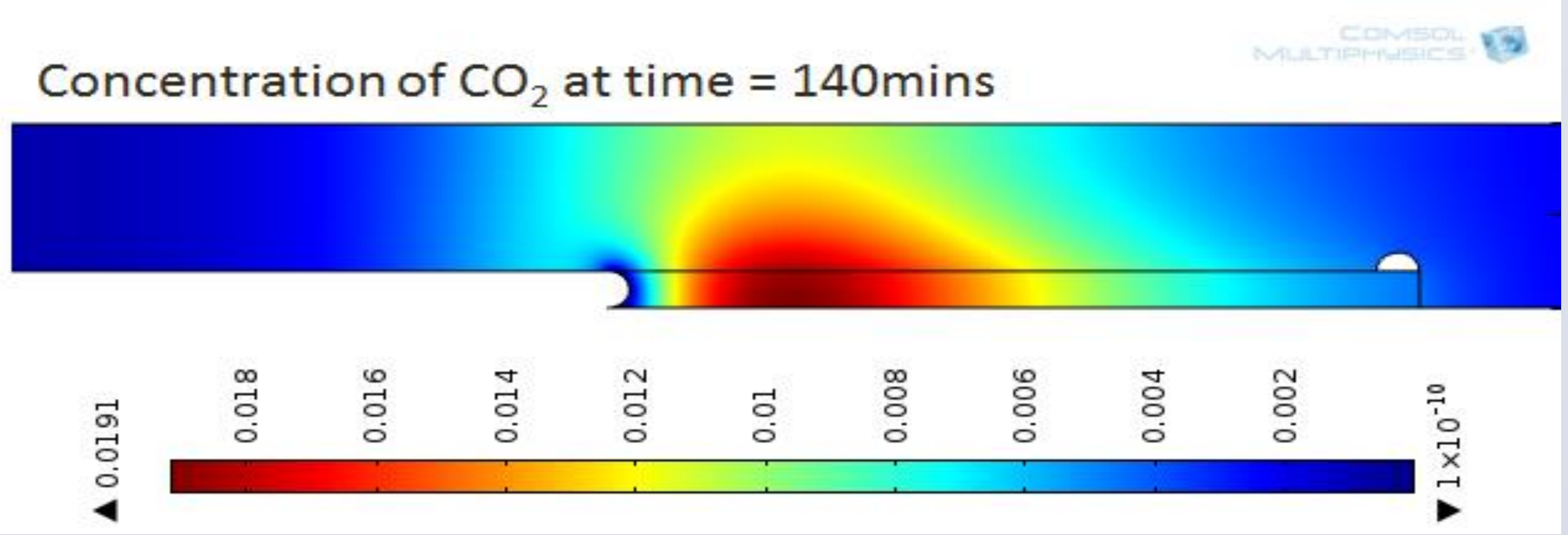

Figure 5. Concentration of carbon dioxide(CO_2) in the coal bed at time=140mins

CONCLUSIONS

The model is able to predict the composition of product gas and its calorific value. The important aspect of the model is that it can foresee the growth of the cavity even after it has hit the overburden, which is the reality for the UCG of thin coal seam.

REFERENCES

1) Tsang, Tat Hang Tate;Modeling of heat and mass transfer during coal block gasification; ProQuest Dissertations and Theses; 1980.

2) E.Shafirovich, A.Varma; U.C.G: A brief Review of current Status, (Ind Eng. Chem. Res. 2009, 48, 7865 -7875

3) C.B.Thorsness, E.A.Grens, A.Sherwood; A one dimensional model for in situ coal gasification; Lawrence Livermore;1978.

4) A.N.Khadse, M.Qayyumiy, S.Mahajani, P.Aghalayam. Reactor Model for the Underground Coal Gasification (UCG) Channel; International journal of Chemical Reactor Engineering; Volume 4, Article A37, 2006.

Excerpt from the Proceedings of the 2013 COMSOL Conference in Bangalore

COMSOL CONFERENCE BANGALORE2013