Int. J. Chem. Sci.: 10(2), 2012, 808-816
ISSN 0972-768X
www.sadgurupublications.com

3D MODEL DESIGN AND SIMULATION OF PHOTOCATALYTIC REACTOR FOR DEGRADATION OF DYES USING SOLIDWORKS SOFTWARE

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ABSTRACT

Recent literature has demonstrated that on a laboratory scale photocatalysis technology to destroy organic pollutants completely present in water has got great potential. In this paper, a new reactor design simulation of reactor (considering thermal analysis) has been carried out using SolidWorks software. The SolidWorks CAD software is a mechanical design automation application that lets designers quickly sketch out ideas, experiment with features and dimensions, and produce models, simulation and detailed drawings. The operating condition of reactor i.e temperature (min. 25^{o}C and max. 80^{o}C) and 1 atm. pressure. As result shows that, the design of reactor is feasible. A reactor was designed and constructed based on the modelling results, and when experiments were conducted showed very promising results. The new reactor aims at developing a technical solution to the design of a commercial scale photocatalytic reactor.

Key words: Photocatalysis, Modelling, Simulation, SolidWorks.

INTRODUCTION

Photocatalysis has been a subject of increasing interest during the last many years. It has indeed various potential applications such as metal recovery, abatement of NO_x, synthesis of ammonia but the recent developments have been induced mainly by the application to the abatement of organic pollutants both in the aqueous and the gaseous phase[1,2]. This development participates to the general concern about the environment and the increasing constraints on the toxicity of wastes[2]. The academic studies have been much developed in the fields of organic chemistry, physical chemistry, chemical kinetics and catalyst preparation, but few studies have been dedicated to chemical engineering and the

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development of reactors. Concomitantly, few industrial processes have been developed[3]. The aim of this study is to give some design aspects of photocatalytic reactor construction based on the modelling and simulation.

SolidWorks software

The SolidWorks CAD software is a mechanical design automation application that lets designers quickly sketch out ideas, experiment with features and dimensions, and produce models, simulation and detailed drawings. A SolidWorks model consists of 3D solid geometry in a part or assembly document. Drawings are created from models, or by drafting views in a drawing document. Typically, we begin with a sketch, create a base feature, and then add more features to our model (we can also begin with an imported surface or solid geometry). We can refine our design by adding, editing, or reordering features. Associatively between parts, assemblies, and drawings assures that changes made to one document or view is automatically made to all other documents and views. We can generate drawings or assemblies at any time in the design process. With a real view-compatible graphics card installed, we can display photo-realistic models and environments. The SolidWorks software saves our work for us with auto-recover. We can also choose to be reminded to save our work. Parts are the basic building blocks in the SolidWorks software. Assemblies contain parts or other assemblies, called subassemblies. A SolidWorks model consists of 3D geometry that defines its edges, faces, and surfaces. The SolidWorks software design models quickly and precisely. The design process usually involves the following steps:

- Identify the model requirements.
- Conceptualize the model based on the identified needs.
- Develop the model based on the concepts.
- Analyze the model.
- Prototype the model.
- Construct the model.
- Edit the model, if needed.

What is SolidWorks simulation ?

SolidWorks Simulation is a design analysis system fully integrated with SolidWorks. SolidWorks Simulation provides one screen solution for stress, frequency, buckling, thermal, and optimization analyses. Powered by fast solvers, SolidWorks Simulation enables us to solve large problems quickly using our personal computer. SolidWorks Simulation comes in several bundles to satisfy our analysis needs. SolidWorks Simulation shortens time to market by saving time and effort in searching for the optimum. Here discusses some basic concepts and terminology used throughout the SolidWorks Simulation software. It provides an overview of the following topics:

Benefits of analysis

After building our model, we need to make sure that it performs efficiently in the field. In the absence of analysis tools, this task can only be answered by performing expensive and time-consuming product development cycles. A product development cycle typically includes the following steps:

- Building our model.
- Building a prototype of the design.
- Testing the prototype in the field.
- Evaluating the results of the field tests.
- Modifying the design based on the field test results.

This process continues until a satisfactory solution is reached. Analysis can help us accomplish the following tasks:

- Reduce cost by simulating the testing of our model on the computer instead of expensive field tests.
- Reduce time to market by reducing the number of product development cycles.
- Improve products by quickly testing many concepts and scenarios before making a final decision, giving us more time to think of new designs.

Basic concepts of analysis

The software uses the Finite Element Method (FEM). FEM is a numerical technique for analyzing engineering designs. FEM is accepted as the standard analysis method due to its generality and suitability for computer implementation. FEM divides the model into many small pieces of simple shapes called elements effectively replacing a complex problem by many simple problems that need to be solved simultaneously. The software offers the following types of studies:

- Static (or Stress) Studies.
- Frequency Studies.
- Dynamic Studies.
- Buckling Studies.
- Thermal Studies.
- Nonlinear Studies.
- Drop Test Studies.
- Fatigue Studies.

3D model design of photocatalytic reactor

The photocatalytic reactor consists of cylindrical vessels 330 mm length and 70 mm diameter with the condensation system , along with the inside tube of 330 mm length and 30 mm diameter and closing cap of 335 mm diameter. The following Fig. 1 to 4 shows the 3D model of each part with assembly of photocatalytic reactor,

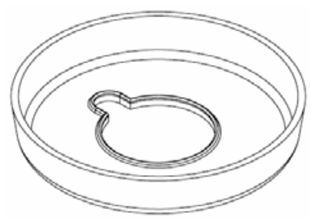


Fig. 1: Closing Cap

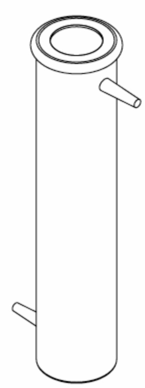


Fig. 2: Cylinder with condenser system

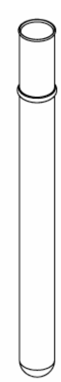


Fig. 3: Inside tube

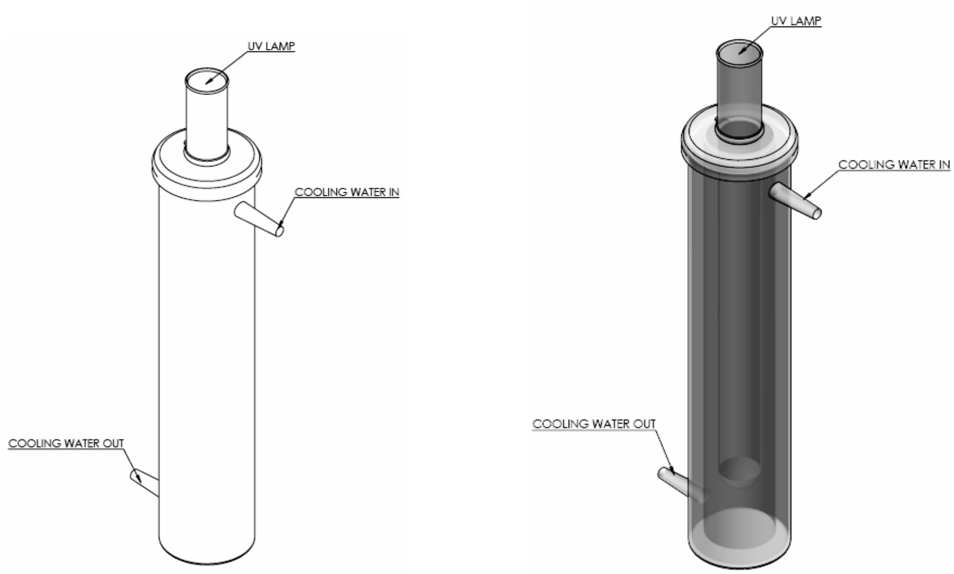


Fig. 4: 3D Model assembly of Photocatalytic Reactor

Simulation of photocatalytic reactor

Assumptions

- No heat losses
- Heat source constant
- Temperature variations along the diameter of reactor

Study Properties

- Analysis type = Thermal (Steady state)
- Mesh type = Solid Mesh
- Solution type = Steady state
- Contact resistance defined = No

Units

- Unit system = SI (MKS)
- Length/Displacement = mm
- Temperature = Kelvin

- Angular velocity = Rad/sec
- Pressure/Stress = N/m^2

Material Properties

- Name = Glass
- Model Type = Linear Elastic Isotropic
- Thermal Conductivity = 0.74976 W/(m.K)
- Specific Heat = 834.61 J/(Kg.K)
- Mass density = 2457.6 Kg/m^3

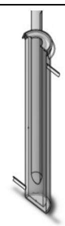
Thermal loads

Thermal analysis calculates the temperature distribution in a body due to some or all of these mechanisms. In all three mechanisms, heat energy flows from the medium with higher temperature to the medium with lower temperature. Heat transfer by conduction and convection requires the presence of an intervening medium while heat transfer by radiation does not. Consider different thermal load conditions on different parts of reactor. The following Table 1 shows the Thermal load data.

Table 1: Thermal load data

Load name	Load Image	Load Details	
Heat Power-1		Entities: Heat power value:	2 face(s) 8 W
Convection-2		Entities: Convection coefficient: Time variation: Temperature variation: Bulk ambient temp.: Time variation:	10 face(s) 7 (W/m^2)/K Off Off 300 Kelvin Off

Cont…

Load name	Load Image	Load Details	
Heat power-2		Entities: Heat power value:	6 face(s) -0.5 W
Temperature-2		Entities: Temperature:	2 face(s) 80^{o} Celsius

Mesh Information

Finite Element Analysis (FEA) provides a reliable numerical technique for analyzing engineering designs. The process starts with the creation of a geometric model. Then, the program subdivides the model into small pieces of simple shapes called elements connected at common points called nodes. The process of subdividing the model into small pieces is called meshing. Finite element analysis programs look at the model as a network of interconnected elements. Meshing is a crucial step in design analysis. The software automatically creates a mixed mesh of solid, shell and beam elements. The solid mesh is appropriate for bulky or complex 3D models. Shell elements are suitable for thin parts (like sheet metals). Beam elements are suitable for structural members. The accuracy of the solution depends on the quality of the mesh as shown in Fig. 5 and Mesh information detail is shown in following Table 2.

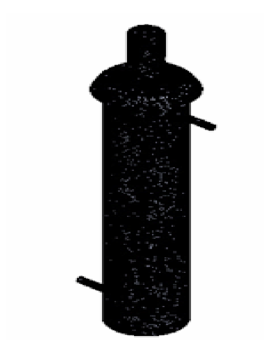


Fig. 5: Mesh quality

Table 2: Detail mesh information

Mesh type	**Solid mesh**
Mesher used	Curvature based mesh
Jacobian points	4 Points
Maximum element size	2 mm
Minimum element size	0.4 mm
Mesh quality	Draft quality mesh
Remesh failed parts with incompatible mesh	Off
Total elements	405998
Maximum aspect Ratio	8.1448
% of elements with aspect Ratio < 3	97
% of elements with aspect Ratio > 10	0
Time to complete mesh (hh; mm; ss):	00 : 01 : 03

RESULTS AND DISCUSSION

From the given thermal condition temperature (min. 25^{o}C and max. 80^{o}C) applied to the photocatalytic reactor, we get that the following result which is the final output of software.

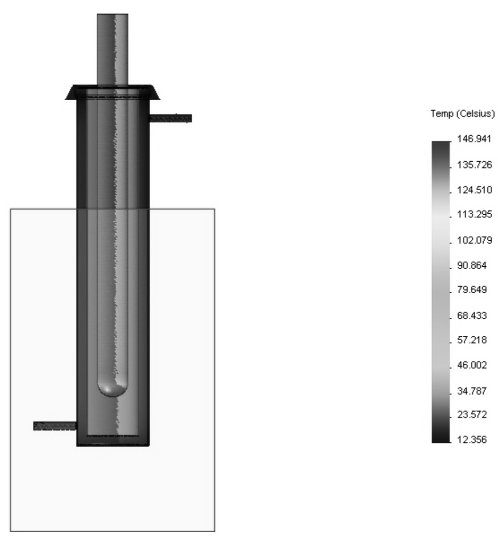


Fig. 6: Thermal Analysis result of photocatalytic reactor

CONCLUSION

Modelling photocatalytic reactors is of importance in order to get true intrinsic kinetic parameters and to carry out the simulation of reactors so as to select or to improve the reactor design. Many phenomena are involved in the modeling which results in the need for effective parameters and in the complexity of the solving of the problem by numerical methods. As the operating condition of reactor i.e temperature (min. 25^{o}C and max. 80^{o}C) and 1 atm. pressure. Thermal analysis shows that, on this operating condition our design of reactor is feasible. A reactor was designed and constructed based on the modelling results, and when experiments were conducted showed very promising results.

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Accepted : 19.04.2012