

THE TEACHING OF UNIT OPERATIONS AT MECHANICAL ENGINEERING

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Abstract *Mixing, with a wide application at industry, can be considered of fundamental importance in major processes. Industrial branches, like food, chemical, drugs, metalurgical and many others are not free of some mixing process in many manufacturing operations. Also, changes at the intensity of the agitation needed for each product, demands that the mixer design turn the most particular for each case, sometimes using fluidized bed. Processes characteristics may bring to viscosity variations, making th e design very difficult and the efficiency evalution as well. The undergraduate student of Mechanical Engineering must be able to deal with a huge variety of problems related to mixing, due to the many field areas that this professional works, not to mention the interaction that can be found nowadays among different areas. What can be found today at the many Mechanical Engineering Scholarship Curriculum is almost nothing related to mixing, even as optional subjects, which can be found mostly at the Chemical Engineering. At the former course, the study of the mixing equipment, whose carry out the processes, is put in a second plan. The goal of this work is to propose a specific discipline for mixing, due to its importance for the Mechanical Engineering course, including contents, number of necessary hours, bibliography and ideal sequence.*

Keywords: *mechanical engineering, higher education, unit operations*

1. Introduction

Unit operations, as mixing and agitation, with a wide application at industry are considered of fundamental importance in major processes and industrial branches like food, chemical, drugs, metalurgical and many others are not free of some mixing process in many product manufacturing operations.

Many of the industrial operations need some kind of physical and/or chemical processes and mass and heat transfer as well, which makes unit operations one of the most spread research areas throughout the world.

Among the many unit operations, agitation has huge importance due to its high presence at many processes and to the empirism which is dealt until now, not to mention the losses it causes, as well.

One mixer device can be designed for only agitation and/or mixing or, in some cases, in order to some intermediate steps of the process, as chemical reactions, may occur. It is also a demand of these equipment that some level of operational flexibility be available in order to allow that mixers work with different liquid levels to attend different demand productions.

There are many agitation levels depending on the product characteristics and so the mixer design must be different as well.

Some particular processes characteristics, as changes in chemical composition may cause viscosity variations, create or eliminate particles, increase or decrease the bulk volume which difficults the design and the mixer performance evaluation, in terms of time and necessary power to obtain some mixture.

At some particular cases it is very difficult to identify the problem in order to choose the right mixing equipment which causes mandatory some itens to be checked.

These itens can be:

- reaction rate enough to carry out the process in some maximum time
- suitable process conditions to achieve the desired product conversion rate
- high production level compared to the waste or by-product produced
- enough heat transfer rate
- temperature or concentration uniform distribution
- particle distribution in some allowed range

Many of the mentioned itens are typically from the undergraduate Mechanical Engineering Course more than the Chemical Engineering one.

On the other hand, some situations must be avoided, for instance:

- particle deposition on the liquid surface
- solids deposition on the mixing tank bottom
- material adhesion on the tank walls
- cold or hot spots on the heat transfer surface

2. Unit operations

The fluid flow pattern in a mixer (Ronchi, 1997) is mainly due to the discharge characteristics of the impeller and so there are some main impellers types, which will, each of them, to produce some very distinct flow patterns.

They are:

- the Rushton turbine, or radial flow turbine, with 3 or more blades, inclined or not
- the homogeneizer, which produces a more tangential flow, having a stator as well

There are many other options available nowadays for Newtonian and non-Newtonian fluids, as a result of the non-scientific based studies to design and manufacture it.

Figure 1 shows the mentioned impellers, which are widely found at many kind of industries that have mixing processes at their products and in Fig. 2 one can see a laboratory batch mixing bench.

Figure 1. The homogeneizer at the left and the turbine on the right.

Figure 2 – A typical laboratory batch mixing bench.

Figure 3 shows one of the types of impellers, well known for its high mixing and agitation efficiency.

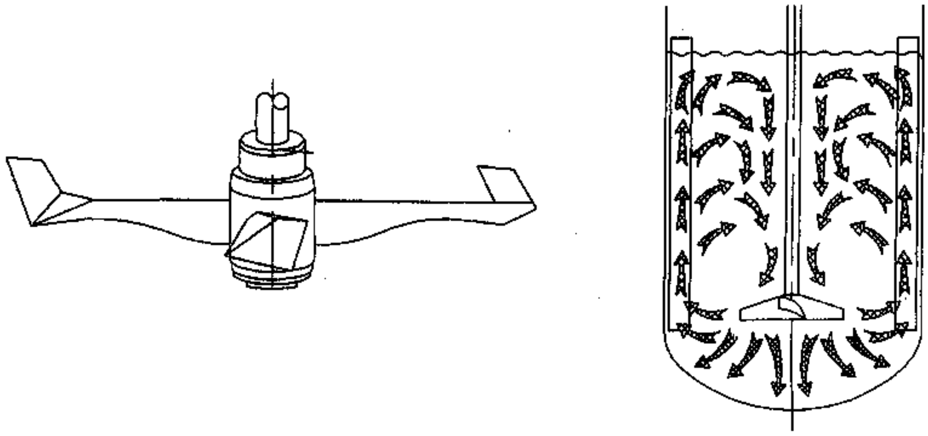

Figure 3 – High efficiency impeller with is correspondent generated flow.

Another unit operations branch is the fluidized bed (Palma, Ronchi and Losnak, 2001), widely used at the powder metallurgy industry, chemicals, food and many others. This kind of process was considered to be mainly empirical with almost no scientific knowledge, causing many desnecessary budget to be expend in research laboratories.

The main reason of the mentioned approach was the great number of variables present in this kind of process, as quantity of particles, density, friction between particles, moisture, electrical charges generated and many others. But, again, the equipment, including its design and manufacturing, plays a major role in the process and, in consequence, makes mandatory the Mechanical Engineer professional.

On a fluidized bed equipment, the solid particles are put over a porous or non-porous plate with holes, where they are kept in a certain suspension level by a gas or liquid flow upwards. This close contact between particles causes a high level of heat transfer and/or mixing. When a state of the art fluidized bed design is achieved, we can find high productivity with small equipments and low power consumption, but on the other way, a bad design causes, e.g., high friction among particles, bad resulting mixture with many differences of density and size inside the batch.

There are many other kinds of different unit operations processes that are described in details in the literature, e.g., Liptak (1987), McKetta (1992), Foust (1990) amont others.

It is important to remind that many of the well known books about mixing and agitation, do not present properly or with the necessary details, some of the aspects that are fundamental for studying the topic, as the impeller and tank design, use of baffles, multiple impellers configuration, influence of rotation speed, power consumption and many other variables (Dickey and Hemrajani, 1992) that affect the overall performance of the process.

3. The role of the Mechanical Engineer at unit operations

It is very ordinary the use of a agitation system performing its work in an pressurized or atmospheric tank.

Only a Mechanical Engineer has the conditions to settle the economic and technical data at the geometrical definition of the vessel and its foundations, as well, attending to the structural stability and, in consequence, defining the plate thickness, with internal or external pressure.

Such parameters demands standards knowledge, materials, processing and shapes and influences of the surface treatment, as well.

Another point to be considered is the knowledge of welding, mainly regarding to thick plates, which is particular to the Mechanical Engineering course.

One agitation system, most of the times positioned at the upper part, requires from the Mechanical Engineer the movement specification, the axle diameter which is sink in a Newtonian or non-Newtonian fluid, with one or more impellers, not to say what kind of bearing support, sealing type, etc…

The processed fluid may require heating or cooling and only the Mechanical Engineer it is able to calculate the heat exchange area, after study the influence of the agitation and tank geometry, as well.

The powder processing, widely used at food and pharmaceutical industry, demands the role of this professional regarding to the dimensioning of the mixer body and also the power and mixing time, which is bonded to the homogenization defined by the process.

There is also the filtration processes, widely used and most of the times under pressure and linked to a pumping process which affects the overall efficiency.

The mathematical modelling it is absolutely fundamental for filtration processes and its knowledge it is used when scaling-up the laboratories processes to industrial plant.

The scholarship *curriculum* of a Mechanical Engineering student is one of the most complete when compared with many other Engineering *curriculum*. One can find very different knowledge areas, including economics, statistics, social sciences, administration and, most important, manufacturing processes, project and design, agricultural, materials, thermal and fluid mechanics sciences.

As referred earlier, it is clear that important aspects of the mixing and agitation processes are close to the topics that are studied during a five years course of a Mechanical Engineering student and many of these aspects are not included at the Chemical Engineering *curriculum*, which is much more related to biology and chemistry, not providing all the necessary knowledge to solve problems related since the design of the mixing equipment to is maintenance.

It is not the goal of this paper to state that it is not important the role played by the Chemical Engineer on the mixing and unit operations find in industry, but instead of that, state very clear that much often the Mechanical Engineer undergraduate student do not learn properly how to deal with such a common subject find in so many production processes.

We have to remember that all undergraduate Mechanical Engineering students already have the main topics related to those necessary to understand quite well unit operations, provided that he will be at the fourth or fifth year of the *curriculum*.

This could be solved with a very simple adding of some few hours in a semester, small in quantity but huge in importance, to the undergraduate Mechanical Engineering scholarship *curriculum* of our students.

This becomes more clear when we check that nowadays one can find many hours beeing loose with topics that nearly will help nothing to the young Mechanical Engineer that starts his career in many industries or even working as a consultant. Actually, in a globalized economy where the world becomes smaller every day, consumption and quality needs grows very fast and the competition among enterprises becomes wild and predatory, many scholarship *curriculum* should go along with this constant changing and, unfortunately, it is not what is happening.

4. Unit operations studies at the present

It is widely known and similar the approach that Chemical Engineering and Food Engineering, as well, not to mention another higher education courses do related to unit operations.

So, we can find, e.g, at Universidade Federal de Santa Catarina/UFSC (http://www.enq.ufsc.br/), course of "Engineering and Food Technology", the subject Unit Operations, code cal5102 with 54 hours/semester with Pharmacy beeing the previous requirement. Some of the topics that are studied here are: solid, liquids and gas separation, liofilization, water technology, drying techniques (drum dry) by convection and conduction, destilation, centrifugation, filtration, sterilization and other, very well related to chemistry and food techology. Their goal is to provide the understanding for the student of the main unit operations on the food field.

Some of the books that are listed at UFSC *website*, are:

- Barthomoai, A. Fábricas de alimentos – processos, equipamentos, custos. Zaragoza: Acribia, 1991.
- Behmer, M. L. Tecnologia do leite. Nobel, 1984.
- Brow, G. G. Operaciones basicas de la inginieria química. Barcelone: Morin, 1963.
- Camargo, R. *et al*. Tecnologia dos produtos agropecuários – alimentos. São Paulo: Nobel, 1984.
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- Fellows, P. Tecnologia del procesado de los alimentos principios y práticas. Zaragoza: Acribia, 1994.
- Gava, A. J. Princípios de tecnologia de alimentos. São Paulo: Nobel, 1984.
- Perry; Chilton. Manual de engenharia química. Rio de Janeiro: Guanabara Dois, 1980.
- Rudolf, P. El empleo del frio em la industria de alimentacion. Zaragoza: Reventé, 1965.

We can clearly check the heading which is given to the course, which is obvious, but wonder the problems that such a professional will have in dealing with project and maitenance of mixing equipments.

At Universidade de Brasília/UnB (http://www.unb.br/) it is the subject Indutrial Physics, code 179442 at Faculty of Health Sciences where the aim is the fundamentals of the pharmaceuticals industry operations and its applications for medicine and food. The books related are:

- Foust, A. S. Princípios das Operações Unitárias. Editora LTC, 1982.
- McCabe, W. L.; Smith, J. C. Operaciones Basicas de Ingenieria Quimica Vol. III. Editorial Reverte (Barcelona), 1987.
- Prista, N. L.; Correia, A. A. Técnica Farmacêutica e Farmácia Galênica. Volumes I, II e III. Fundação Calouste Gulbenkian (Lisboa), 1979.
- Shreve, R. N.; Brink, J. A. Indústrias de Processos Químicos. 4a. ed. Editora Guanabara, 1997.

Also at Universidade de Brasília there is Water Treatment, very specific and also with no topics related to equipment, making it not suitable for solving many problems related to those equipment that is often present in such a plant.

Its bibliography is:

- Awwa, Water Quality and Treatment - A Handbook of Public Water Supplies, Fourth Edition, McGraw-Hill Book Co., Estados Unidos, 1990.
- Bryant, E.A. et al., Desinfection Alternatives for Safe Drinking Water, Van Nostrand Reinhold, USA, 1992.
- Di Bernardo, L., Métodos e Técnicas de Tratamento de Água. Volumes 1 e 2, ABES, Rio de Janeiro, 1993.
- Kawamura, S., Integrated Design of Water Treatment Facilities, John Wiley & Sons, Inc., USA, 1991.

At Universidade de São Paulo/USP (www.usp.br), Hydraulics and Sanitation at Civil Engineering and Production Engineering, one can find Unit Operations I, code PQI2303, 4 credits, related to piping, pumping, steam, compressible fluid flow, fan, compressors, filtration but nothing related to tank and impeller design, operation and maintenance. Its goal is give the student the unit operations concept for the chemical industry related to fluid transport and suspension splitting based on transport phenomena.

At PQI2310 – Chemical Processes, 4 credits: batch processes studies, material and energetic balance, operational characteristics at the unit operations at chemical industry and instrumentation/maintenance as well. There is also a topic with some examples of some chemical processes at the brazilian industry, doing a relationship among unit operations and the operational characteristic. In some level, we can say that we found a little of Mechanical Engineering, but not enough.

The main bibliography is:

- Austin G. T. Shreve´s Chemical Process Industries, 5 th. ed., McGraw-Hill Book Company, 1984.
- Cook T.M., Cullen D.J. Chemical Plant and its Operation, 2 nd. ed., Pergamon Press, 1980.
- Foust A. S. *et al*, Princípios das Operações Unitárias , 2ª ed. Ed., Guanabara Dois ,1982.

At Universidade de Campinas (www.unicamp.br), Food Engineering, there is Unit Operations, code TA735, dealing with agitation, mechanical separation, heat exchangers, heat transmission and equipment for fluid flow. So, again, we find something related but a small part of the necessary knowledge for solving problems on its whole.

We could extend our research to many other courses and institutions, including abroad, to check and conclude that are some topics missing at the *curriculum* which not allows to the professional solve many problems as one undergraduate Mechanical Engineering could do with a more suitable approach of agitation and mixing.

5. A proposal for unit operations at Mechanical Engineering undergraduate course

As exposed, it is very clear the importance for the undergraduate student of Mechanical Engineering have a wide view of many topics related to Unit Operations, which includes agitation and mixing.

The kind of approaching that we dealing about includes not only some chemical aspects, but most the design, manufacturing and maintenance of the tank-impeller unit, which together plays, as we know, the main role on the mixing operation. This also includes some very particular aspects, as welding and materials, not to mention other ones, that Chemical Engineering undergraduate students usually do not study.

We must remember that materials, design, welding are already in most of the Mechanical Engineering courses and so this is already an advantage for this students.

The other main requirements for unit operations at one Mechanical Engineering course are Fluid Mechanics, Thermodynamics and Heat Transfer.

The main topics to be studied are:

Unit Operations I

- Tanks, mixers and reactors: 30 hours
  Contents:
  Geometry criteria: main parameters
  Latch covering
  Sustaining system
  Pressure vessels
- Fluid agitation: 30 hours
  Contents:
  Mathematical modeling
  Mechanical components dimensioning
- Heat exchange in tanks: 30 hours
  Contents:
  Building options
  Heat exchange surface area calculation
  Thermal insulation

Unit Operations II

- Powder mixing: 30 hours
  Contents:
  Mixer types
  Required movement definition

Mixing time

- Filtration: 20 hours

  Contents:

  The filtration process

  Mathematical modeling

- Scaling-up criteria: 10 hours

As a consequence of the exposed, the necessary schedule would be 90 hours for Unit Operations I or 6 credits or 15 weeks, and 60 hours for Unit Operations II or 4 credits or 15 weeks in one regular semester. One credit is one hour of lectures per week. Our suggestion is to be considered a mandatory subject at the 5th year, as well.

Bibliography can be very wide and we can list some of the present good books that deal with the subject, not to mention, of course, many research papers that are published about it.

Some of the good one, nowadays, are:

- Arpe, H.J., Gerhartz, W., Davis, H.T., 1988, "Unit Operations I, Vol. B2, Ullmann's Encyclopedia of Industrial Chemistry", 5th Edition, USA, 652 p.
- Arpe, H.J., Gerhartz, W., Davis, H.T., 1989, "Unit Operations II, Vol. B3, Ullmann's Encyclopedia of Industrial Chemistry", 5th Edition, USA, 691 p.
- Azbel, D., 1983, "Fluid Mechanics and Unit Operations", Ann Arbor Science, USA, 1160 p.
- Blackadder, D.A., 1971, "A Handbook of Unit Operations", Academic Press, USA, 284 p.
- Gould, W.A., 1996, "Unit Operations for the Food Industries", CTI Publications, USA, 182 p.
- Ibarz, A., Barbosa-Canovas, G.V., 2002, "Unit Operations in Food Engineering", CRC Press, USA, 920 p.
- McCabe, W., 1976, "Manual to accompany unit operations of chemical engineering", McGraw-Hill, USA, 248 p.
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- National Food Processos Association Research Foundation, 1981, " Energy conservation in the canning industry: Phase II, measurement of energy used in unit operations – final report", USA, 542 p.

6. Conclusion

It is fundamental for the undergraduate Mechanical Engineering student have this basic knowledge of unit operations, with the suggested approach, different from the one taken by the Chemical or Food Engineer, considering the wide field area that this professional will work and also due to the thousands of products that be found nowadays that uses some kind of agitation or mixing in its manufacturing process.

We can also state that the strong competition between industries, bring to the mechanical engineer the growing need of decrease production costs and raise the quality of the final product, as well, without to depend on the others branches of engineering.

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