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Discussion Forum
Engineering Education Requirements for the Pump Industry Academic and Industrial Views*

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A panel of industry representatives and academicians were brought together to discuss engineering education requirements from the pump manufacturer's point of view, during the Pumping Machinery Symposium at the Third Joint ASCE/ASME Mechanics Conference, San Diego, 1989. Methods to promote continuing technical progress and excellence in the field of pumping machinery were explored.. The mechanisms for training and enhancing pump engineers' knowledge were discussed. The discussion included methods of generating support for training of engineers, the use of cooperative education programs, the low level of student interest in the pump industry, the market for engineers in the pump industry, increased industry-university cooperation, the use of graduate courses, need for strong basic engineering education, etc. The discussions and panelists' viewpoints are discussed in this paper.

INTRODUCTION

THE objective of the panel discussion on 'Engineering Education Requirements for Pump Industry', held during the Pumping Machinery Symposium at the Third Joint ASCE/ASME Mechanics Conference, San Diego, California, 1989, was to explore how to promote continuing technical progress and excellence in the field of pumping machinery. Pumping machinery is extensively used in fields which include Power generation (fossil fuel, nuclear, hydraulic and wind), Aerospace, Defense (Navy, Air Force, Army), Public works, Automotive industry, Chemical industry, Petrochemical, Agriculture and other industries. With such a wide application of pumping machinery, the education and training of the pump engineer starting from the engineering student level is of great importance. Fundamental areas involved in pumping machinery include:

- Fluid mechanics
- Bearings, seals and vibration
- Overall design
- Material
- Manufacturing
- Marketing
- Performance and testing
- Power sources (electrical and mechanical drives)
- Standards and Codes
- Service and trouble shooting.

How does the pump engineer develop his knowledge and expertise at present? The knowledge and expertise gathering process starts at the undergraduate engineering student level. Courses in areas of fluid mechanics, materials, fluid and thermal design, dynamics and vibrations, computer

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aided design, mechanical engineering laboratory, report writing, etc., all aid in this process. Schools involved with Co-op programs allow the student to have greater interaction with industries in school years which results in a better understanding of the industries concerns and requirements. The knowledge gathering then sometimes extends into graduate school where it is further enhanced by taking courses concentrated in specific areas. Essentially the basic engineering skills required for a sucessful engineering career are developed at the engineering school. However, the requirements of the pump industry are much more specific and are focused on the product, i.e., the pump. Thus, the basic engineering skills have to be augmented by the specialized skills needed for the product. In the professional career, the pump engineer is trained in the industry by his peers and benefits from their experience and knowledge and develops these specialized skills. This on the job training process is enhanced by in-house seminars/courses, professional short courses and in some cases attending graduate school. The net result is the transfer of knowledge and technology to the newer generation of pump engineers. The process started at the undergraduate engineering student level continues through the engineer's career in the pump industry. The academia-industry interactions from the point of view of increasing and further developing and enhancing this technology transfer are therefore very important.

The panel brought the academicians and the industry personnel together to discuss the engineering education aspects from the pump manufacturer's point of view. The panelists included representatives of the industry and academia. Representing industry were P. Cooper (Ingersoll-Rand), S. Gopalakrishnan (Byron Jackson), and A. E. Hribar (Westinghouse Electric Corp.). Academia was represented by A. Acosta (California Institute of Technology), and G. S. Jakubowski (Memphis State University), and J. R. Kadambi (Case Western Reserve University) served as Panel Moderator, W. Peng (California State University, Fresno) was Co-Session Chairman.

PANELIST'S VIEWPOINTS

The interactions with the attendees were preceded by short presentations from the panelists.

Engineering Education Requirements for the Pump Industry—An Industrial Researcher's Viewpoint Paul Cooper (Ingersoll-Rand Company)

To establish a position or positions regarding engineering education for the pump industry, it is convenient to look at the hydraulic design and performance prediction challenge. One could reach similar conclusions by considering rotordynamics, vibrations, etc. In this vein, a sucessful pump design is either theoretically and/or experimentally the solution of a very complex fluid dynamic problem—involving turbulent, unsteady, viscous, 3-D flow in two fields interacting (for each stage) i.e., the impeller and diffuser (or volute) flow fields.

On the theoretical side, we have seen many advances in the application of fluid mechanics to the solution of this problem; in particular, (a) work on 3-D viscous flow schemes; (b) graphically displayed computer solutions of unsteady interaction flow between axial-flow blade rows; (we have yet to see this applied so successfully and credibly to radial flow machines); (c) but at least, of late, we have seen experimental/theoretical studies of the unsteady, interacting force fields of impeller and diffuser (or volute) of radial flow machines (one in this symposium) and (d) of course, the work on two-phase flow (some of which we have seen illustrated in this symposium, *Pumping Machinery*—1989, ed. P. Cooper, FED Vol. 81, ASME, New York, NY.).

Making progress in these areas demands continuing dedication to and excellence in both experimental and theoretical applied fluid mechanics—to both single and multi-phase flows. This would seem to be mainly the province of graduate study programs—with particular emphasis on real machines. Engineering students are not pure scientists: to be true engineers, they need to be motivated by the practical application of and need for their work and effort.

But over against this necessary and commendable effort to hone theories and so make them more reliable and more useful as tools for designing, we have the practical design engineer who cannot wait for the ultimate theoretical description of the phenomena he must deal with in producing results. At any point in time, the pump engineer needs a working design system that he can use easily—and not just to generate a single pump design but very often a whole line of variously-sized pumps. To do this successfully, he must be an astute mechanical engineer with an uncanny commercially competitive sense. his engineering background must be unceremoniously applied with dependability and rapidity to provide his company with a viable product at an absolutely minimum cost.

Harold Anderson, in a recent private communication, contrasted his very useful 'area-ratio' hydraulic design concept to a statement made about centrifugal pumps at the IMechE 1987 International Conference on Turbomachinery—on Efficiency Prediction and Improvement, quotes as follows: 'The peak efficiencies achieved are about 80 percent overall .... development of existing designs requires very difficult work . . . the only way forward is with fully viscous Navier Stokes solutions.' In his frustration, Anderson (who has designed many successful commercial centrifugal pumps) gives several examples of what he calls 'academic exam questions'—apparently problems from textbooks—in which these answers are off by as much as 100%!

From the background success of his design system he throws out this challenge: 'The serious matter is the training of our graduates in the production of pumps that will work. It is of no use to make a pump that only delivers half its guaranteed flow'!

Now, out of fairness to today's theoreticians, there has been a lot of progress in performance prediction. We have seen some of it at this symposium. As Anderson himself never tires of telling us, Worster's essentially one-dimensional theory proved the validity of his area-ration method.

Of course, the advance work needed to design reliable high-energy and other speciality pumps involves a lot more than mere performance prediction. Here we need advanced fluid dynamical, rotordynamical, structure, tribological and materials understanding.

Perhaps the best way to educate pump engineers would therefore be to combine a strong mechanical engineering curriculum—including practical fluid mechanics and turbomachinery studies with extensive laboratory and field experience—through co-operative education perhaps—in the design, manufacture, installation and maintenance of impeller pumps. A similar conclusion could be reached for positive displacement pumps. The motivated, intelligent engineer should then be able to apply this educational background to the requirements of today's pump industry. This approach must be backed up, as always, by a vigorous and dedicated graduate program to advance the science of pumping and its application to tomorrow's pump industry.

Engineering Education Requirements for the Pump Industry—A Manufacturer's Viewpoint, S. Gopalakrishnan (Byron Jackson Products)

I would like to begin first by reviewing briefly the nature of the engineering work at a company like Byron Jackson. Our company manufactures a wide range of centrifugal pumps for the power, petroleum and waterworks industries. Our products require a broad spectrum of engineering requirements—from routine or 'standard' pumps which require very little engineering to highly sophisticated one-of-a-kind pumps which require many hours of exacting engineering. The engineering activity varies with the nature of the product and this is roughly classified as below:

- *Standard products*. Typically field salesmen select a suitable pump from the catalog based on the customers' requirement. Engineering generally needs only to review the selection and release the bill of materials. Since witness testing or customer hold points are usually not invoked, engineering does not get much involved in the manufacturing, testing and delivery of the product.
- *Products requiring minor upgrades*. These may be commercial or nuclear products in which either due to customer desires or due to cost reduction/performance improvement goals, certain design changes are made. For the nuclear industry, these will generally have to be certified by means of computer based analysis.
- *Major projects*. These involve new orders requiring a great deal of engineering attention to meet performance requirements. Typically, these projects require very close coordination between engineering and the customer, starting at the time of project initiation and continuing all the way through delivery, and field testing and performance.
- *New Products*. These usually emerge after several months or years of activity in the Research and Development Section. In the last few years, a great deal of attention is being paid to expertise in non-typical areas, e.g., computer based diagnosis.

Even though the level of engineering activity varies with the type of product, there are certain common engineering skills required to satisfactorily execute the tasks. These are described below:

- *Machine element design*. A thorough understanding of the performance and limitations of machine elements is very important in pump design. This will help to properly select the bearings, seal, lubrication systems, couplings, heat exchangers, etc. In nearly all pump projects, these elements will have to be selected by the engineers. Even though in our company, these elements are typically buy-out items, engineering is responsible for proper integration of these components into the pumps and for their trouble-free operation. We would like our engineers to have a solid understanding of the material in a textbook like that of Shigley's '*Mechanical Engineering Design*'.
- *Machine design*. The mechanical design of machine components is a skill that grows with experience. However, a good understanding of stresses and deflections due to pressure, thermal and other loadings is critical. Also, a knowledge of allowable stresses for various materials under different conditions is necessary. For nuclear products, the allowable as defined by various code sections need to be well understood. To perform these functions satisfactorily, the engineer must be well grounded in basic strength of materials, an elementary engineering metallurgy. Textbooks on strength of materials, dynamics, and mechanical vibrations will provide a sound basis for developing this skill.
- *Analysis*. For most advanced products, computer based stress and deflection analysis are needed. Expertise in computer programs like ANSYS or NASTRAN is needed, but can be developed on the job. But, a skill to use

modern computer programs on main frames and PCs is very valuable and ought to be developed in school.

- Communication skills. Most engineered products require documentation in the form of design or test reports, procedures, etc. Some very skillful engineers do not write well, because of an inability to organize their thoughts resulting in a lack of coherence and cogency in written and oral presentation. I believe engineering students must be taught the basics of report/memo writing.

I would also like to mention at this point that we have been very pleased with the CO-OP program which is part of the California Polytechnic School System. The students are encouraged to take a break from the school and work in the industry for a period of six months on a full time basis. The students return to school with a much better understanding of the industry's needs and they are usually well-positioned to take the right courses and make the right choices regarding their careers. I believe the school faculty also gets a reasonable insight as to how their courses should be structured.

Finally, I would like to remind the reader that the foregoing represents the perspective of the Chief Engineer of a pump company with primary focus on job engineering rather than research and development. I am sure others in the industry with a different focus might express quite different requirements for engineering education.

Engineering Education Requirement for the Pump Industry—A Viewpoint of Manufacturer of Pumps for Nuclear Industry A. E. Hribar (Westinghouse Electric Corporation)

An identification of the general and specific engineering education requirements for this industry requires an examination of the specific characteristics that differentiate pump products from other engineered products. A further differentiation, albeit a finer distinction, is required for the type of pump products produced by Westinghouse's Electro-Mechanical Division (WEMD) as opposed to those that may be produced by other manufacturers.

The products produced by WEMD can be roughly characterized as mixed or centrifugal flow pumps operating in high temperature and pressure fluids, driven, in most cases, by electric motors. Some of these pumps operate at variable speeds. In addition to performance, reliability and maintainability features are of paramount importance to our customers.

Clearly, the design and manufacture of pumps requires sound basic engineering skills in mechanical, electrical, fluids and manufacturing engineering. Beyond that however is a requirement for specialized skills that address specific issues critical to the success of pump products. These skills include hydraulic design, electric motor design, rotor dynamics, bearing design—tribology, materials, weld design and fabrication, and testing. In almost all of these areas, the specialized skills required have historically been developed by on-the-job training or the hiring of individuals that have prior direct experience.

In particular, hydraulics has been a highly empirical science, where expertise has been developed over many years of actual practice. Recent advances in computational flow dynamics (cfd) have reached a level of sophistication where science has begun to replace empiricism for some basic hydraulic computations related to the design and fabrication of impellers. Since the impeller design (efficiency and performance) is crucial in determining most of the rest of the pump and size requirements, advances in methods that can enhance the design are very important. Consequently, knowledge and familiarity with cfd will be a requirement in the future to function in this area.

Another area of concern is that of electrical engineering for power machinery (motors). The number of electrical engineering graduates that have education and an interest in power machinery, as opposed to electronics, is quite small. Yet, enhancements in the design and performance of the electric drive motors of pumps is a very vital requirement. Newer methods, such as the ability to apply finite element methods for electromagnetic field analysis, have become necessary tools of the trade. Thus, there is a real market need for engineers with specialization in power machinery.

Rotor dynamics, structural analysis and bearing technology are all strongly related. The bearing designs are a crucial determinant of pump critical speeds, structural loading and overall pump reliability and availability. Finite element analyses to calculate dynamic loads, operational stresses and failure margins are standard tools of the trade today. Education in finite element methods, rotor dynamics concepts, structural analysis methods (and ASME code requirements for pressure boundary components) and tribology are essential for engineers to function in these areas.

Materials, and manufacturing and test methods are equally important areas. With the constant development of new materials, demands for higher performance and reliability within smaller physical envelopes, and operation in hosile environments, the demands for materials expertise is more and more important. Similarly, pressures to manufacture and test products at lower cost and more quickly require continued innovation in manufacturing, fabrication and testing techniques.

Because the numbers of people that any one manufacturer requires with some of these highly specialized skills is very limited, it is unlikely that engineering schools will be able to directly meet all of these needs. However, curricula that include the sound basic engineering foundations along with up-to-date results of recent research and development, as always, will permit industry to further train graduates to meet these specialized needs.

One underlying theme of all of the requirements for design and analysis functional skills is the ability to understand and work with computer-aided engineering tools. CAE has become a very generic term. However, it is clear that to continue to advance the state of the art and build higher performing products for more demanding applications at prices customers are willing to pay requires the application of computer tools that permit more exact evaluation of short-cuts and rules-of-thumb that, in the past, were necessary in order to produce a workable product.

Educating Students for the Pump Industry—An Engineering Education Administrator's Point of View Gerald S. Jakubowski (Loyola Marymount University)

Without a doubt, little is currently done beyond the basic fluid mechanics course for educating and preparing engineering students for potential work in the pump industry. There are many reasons and possible solutions to the problem.

First, it is important to bear in mind that the purpose of an undergraduate engineering education, whether it be in mechanical engineering, electrical engineering, or whatever, is, or at least should be, to develop a person with enough versatility without over specialization who can enter many types of industry. It is also important for engineering education to keep pace with the rapid changes in the technology.

Engineering education has attempted to keep pace with technology by incorporating new courses into the engineering curriculum. However, at the same time it is important to continue teaching the basic engineering core courses. For example, courses in computer graphics and computer-aided-design have been added into the curriculum by many engineering departments. However, many engineering educators believe the 'lead' graphics still needs to be taught before an understanding and appreciation of 'computer graphics' can be learned. Relating this to the pump industry, how can a student be expected to understand the mechanics of pump operation without a basic course in fluid mechanics?

The above leads to the dilemma currently facing those responsible for developing engineering education curricula—how to prepare students for industry by teaching them current engineering methods and perhaps , so-called 'high-tech' courses while at the same time maintaining the teaching of basic engineering courses.

The above problem is compounded further with the renewed interest taking place at many universities in their desire to add more required courses from the humanities and the social sciences. Many universities believe that all graduates should have breadth as well as depth as part of their college education. Therefore many universities have developed a core curriculum whereby it is necessary for all students to take a minimum number of hours in several different subject areas. Whereas the concept has the best intentions for developing a well rounded educated person, it nevertheless limits the number of credits remaining for engineering courses.

Currently, ABET considers a program to consist of 128 semester hours or 192 quarter hours. Many engineering programs already exceed these minimums. Furthermore, because of the introduction of many new courses into the engineering curricula as 'required' courses (e.g., CAD/CAM, Computer Graphics, Microprocessors, Finite Element Analysis, etc.), many engineering programs have very few engineering 'elective' courses remaining.

To summarize the above, engineering colleges are faced with maintaining the engineering degree as a four-year program, while simultaneously forced to keep offering basic engineering courses, add humanities and social science courses and add new engineering courses that industry deems necessary.

One solution to the above problem is to make engineering a five-year program. However, many engineering colleges are reluctant to do that unless all engineering colleges jump on that same bandwagon together.

It would appear that there is little that can realistically be done immediately at the undergraduate level to address the needs of the pump industry. At best, limited coverage of pump associated material can be covered in existing courses such as in fluid mechanics or in design of thermal systems. Elective courses can be developed. However, as cited above, many colleges have few hours available for elective courses.

A related problem deals with the textbooks that are currently available for courses. Very few of the leading textbooks used for fluid mechanics courses present material on pumps. As a matter of fact, very few even mention net positive suction head. As a result, many graduates are not prepared to select a pump for a given application, let alone deal with the problems associated with the design and operation of a pump.

To correct the matter, authors will need to incorporate new chapters on pumps and pumping systems into existing textbooks. In addition, new textbooks that address pumps and pumping systems exclusively need to be written.

It would also apear that the graduate level would be the most likely place to address industry's needs or additional coverage of pumps and pumping systems. Here again, new courses and textbooks need to be developed.

Briefly summarizing, I would agree that there is a legitimate concern on the part of the pump industry on the need to better educate students on the subject of pumps and pumping systems. It would appear that the graduate level is the easiest area to address the problem. In addition, authors need to incorporate additional material on pumps and pumping systems into existing textbooks and more textbooks addressing pumps exclusively need to be written. Discussions on the purposes of engineering education need to take place amoung universities, industries and the accrediting agencies. Most importantly, a spirit of cooperation needs to exist with all concerned.

Viewpoints of Professor A. Acosta

Professor Acosta raised some interesting viewpoints in his presentation. These include:

1. The pump industry is not one of the 'popular' or 'glamorous' areas of interest as perceived by today's students.
2. There is a question of how large a market there is for engineers with training tailored for the pump industry. Relatively speaking it is small.
3. Similarly, there is then the question of where support for advanced training of engineers to serve the pump industry is going to come from, if there is a need for such training.
4. The pump industry must invest directly in its future by supporting and performing both internal and external research.
5. Industry-university cooperation is very common in Japan and Germany. The establishment of university fellowships, for example, has provided many benefits to the industry. This could be a vehicle for providing specialized training for the pump industry.
6. Today, probably 90% of all pump related published research has been funded by government agencies (NASA, etc.).

SUMMARY OF PANEL DISCUSSIONS

There was a lively discussion following the panelists presentations. The following summarizes the comments from the session participants.

One method of generating support for the training of engineers and the development of technology to support the pump industry is the establishment of university consortia (funded by contributions from a number of interested companies).

Cooperative education programs have been found to be an effective source of obtaining new engineers by several of the participants' companies. The industrial assignments within a pump company provides the company an opportunity to not only examine the student but also to expose and train the student in pump related technologies that may not be part of the standard engineering curriculum. One potential way to address training needs for the pump industry would be to develop a 'special' summer program at the undergraduate level devoted to issues/technology associated with pumps/turbomachinery.

Some significant discussion ensued about the lack of 'good' textbooks in turbomachinery. It was noted that suitable textbooks exist in Japan and Germany and that turbomachinery courses are part of their undergraduate curriculum. It was ventured that if there was really a demand for such a textbook, there should be sufficient support to generate an English translation of one of the existing books. Two relatively new textbooks at senior-first year graduate level were also mentioned.

It was also noted that many universities include elements of turbomachinery in their undergraduate fluid mechanics course(s). But in general, it was observed that there was no room in the typical undergraduate curriculum for a turbomachinery course or an elective because of the demands from so many other subject areas, including the humanities.

In many cases there is a lack of knowledge on the part of end users as to the impact of overall system considerations and what happens when a pump is installed into a plant system. Consequently, rather than just providing education for pumps, there should be education provided that addresses systems and applications.

One participant noted that from an operating plant perspective, he did not like pumps because they are a source of many problems. They are a very complex product. Thus, when engineers are taught about pumps, they need to be taught to think and to examine possible consequences of the designs they are developing.

These interactions it was felt, are useful in developing a better appreciation of the industries requirements and also the bounds in which the academicians have to work in a four year time frame to train engineers well-educated in all the basic engineering skills. Some of these ideas may provide avenues for further improving the training of engineers involved in the pump industry.