Bombay Technologist

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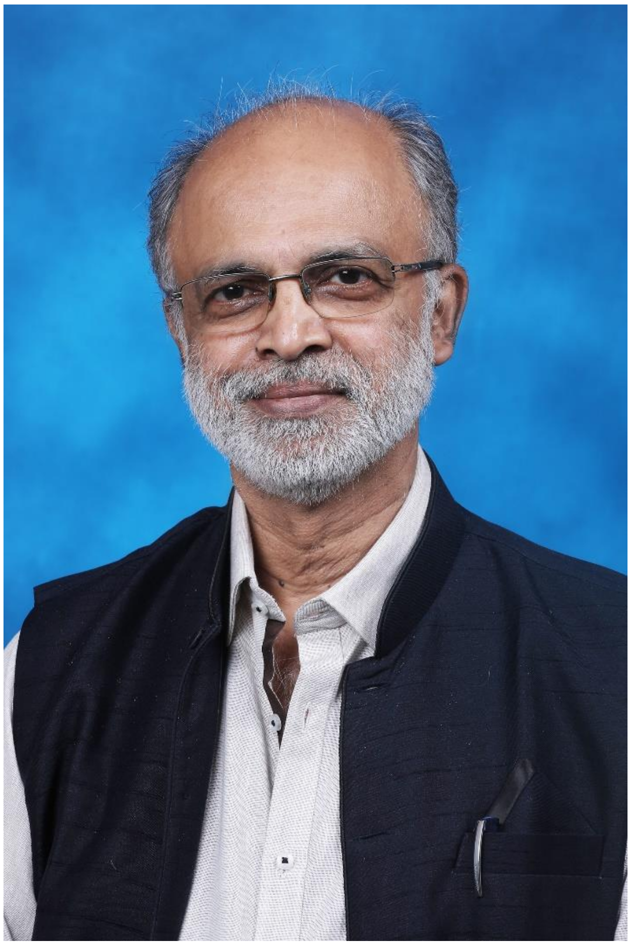
An interview with Vice-Chancellor Prof. A. B. Pandit

About Prof. A. B. Pandit:



Prof. Aniruddha Pandit is the Vice-Chancellor of the Institute of Chemical Technology and a member of the Board of Governors of IIT Bombay and the Heavy Water Board of Department of Atomic Energy. Prof. Pandit completed his B.Tech in Chemical Engineering from the IIT BHU in 1980 and earned his PhD in Chemical Engineering from UDCT (now ICT) in 1984. He worked as a Research Associate with Prof. J. F. Davidson at the University of Cambridge from 1984 to 1990. On returning to India, he joined ICT as a Research Scientist and was subsequently promoted to the position of a Professor. His research interests include Cavitation, Sonochemistry, Ballast Water Treatment, Mixing in Mechanically agitated contactors, Modelling of Stoves, Use of non-conventional energy sources and Biotechnology. Prof. Pandit has avidly authored over 400 publications, 5 books and over 13 chapters and has been cited over 26000 times. He has 16 patents under his name and is on the Editorial Board of 5 International Scientific Journals. Prof. Pandit believes in using applied research to solve problems pertinent to Indian society. He has developed a modification of the traditional hand pump that uses hydrodynamic cavitation to produce potable water. The same technology is also being used to clean several lakes throughout India. He has also developed highly efficient solid fuel burning stoves which leads to lesser wastage of fuel.

1. What motivated you to pursue chemical engineering? After completing education, why did you opt to enter the academia rather than the industry?

My father was a chemist himself. He had completed his M.Sc in Chemistry in the 1940s. He used to tell me that he did not see the utility of chemistry in day to day life. He was the one who pushed me to pursue chemical engineering at that point of time because he wanted to see, how chemistry can be put to use, using engineering principles. So, one of the major reasons for me to get into Chemical Engineering was my father's background and his push.

There were two specific reasons as to why I chose to enter academia. Firstly, everyone in my family was in academia. My mother, father, grandmother and grandfather, all were teachers. As a result of this, it is as if teaching and academia are in my genes.

Secondly, to get into academia, a PhD is necessary. My father couldn't do his PhD because of some conditions but he used to even guide PhD students in those days. So as a result of my father's push and his desire and my liking for teaching, I decided to pursue academia. To get into academia, a PhD is a must, so I decided to do a PhD.

2. You have worked extensively on the applications of hydrodynamic cavitation. What is the simplified concept behind hydrodynamic cavitation?

To answer this question, I must tell you the history of hydrodynamic cavitation. When I completed my PhD and went to Cambridge to pursue a post-doctoral, I was associated with a project which was sponsored by ICI (Imperial Chemical Industries). This project involved the biosynthesis or microbial synthesis of biodegradable polymers, poly butyl acid and polybutyrate. These polymers are synthesized by microbes and they store these polymers within their cells. To recover these polymers, it is necessary to disrupt the cells. The cells are disrupted, the polymers are leached out and then extracted. Further processing is similar to that of other polymers.

There were different methods which were followed for the disruption of these microbial cells which were loaded with the polymers. In this entire chain of steps of biodegradable polymer synthesis, cell disruption was the costliest and most energy-consuming operation. Being an engineer, it was necessary to have a look at all the processes which were followed to disrupt the cell such as high-pressure homogenizer, high-speed homogenizer, French press, bead mill and so on. So, I started analyzing each of this equipment scientifically and hydrodynamically and to my astounding conclusion, I realized that the maximum cell disruption occurred when all of this equipment was operated in a cavitating regime, that is, hydrodynamic cavitating regimes. This means that the equipment had to be run at a specific speed and fluid velocity for the cavitating conditions to be generated. The collapsing cavities would disrupt the cells, leaching out the biodegradable polymer.

Following the principles, I started looking at the fact that if at all cavitation is responsible for cell disruption, are there any simpler means to generate hydrodynamic cavitation? So, we performed a preliminary experiment. The fermentation broth with the cells in it was taken and it was circulated with the cell within the vessel. Downstream of the pump, was a valve that was throttled which created a mechanical constriction leading to an increase in velocity. As per Bernoulli's principle, an increase in velocity leads to a decrease in pressure. This created cavitating conditions when the reduced pressure matched the vapour pressure of the medium which was mostly aqueous. It was surprising that using only 1% of the energy that was used otherwise by the other equipment, the cells could be disrupted most efficiently. This was the most exciting period.

First was the serendipitous revelation of the fact that hydrodynamic cavitation can be effectively utilized. This prompted me to start a new area of hydrodynamic cavitation. The first paper appeared in 1992 in a Washington conference and the first publication also appeared in 1992. I had a huge problem getting this first paper published mainly because nobody had done or proposed anything like this, and so nobody was ready to believe or accept that something like this could be done. We struggled for 8 years. In the year 2000 when I participated in a conference in Italy that was conducted by the Ultrasonic society, I was chairing a session where Professor Detlef Lohse of the University of Netherlands gave a plenary lecture. In this lecture, he showed with the photograph and analysis that even nature uses cavitation. He showed a film of the snapping shrimp that uses cavitation to stun its prey and render it immobile. So after 8 years of struggle, people realized the fact that if cavitation is used by nature, then it is possible. Now, the only objective of engineers is to create it at multiple locations and using the least amount of energy. This is how the entire research area of hydrodynamic cavitation started.

3. What are some applications of hydrodynamic cavitation?

The first work started with the disruption of cells. This same work continued. We also did an elaborate mathematical modelling and fluid mechanical analysis of the cavitation phenomena. Disruption of the cells to recover intracellular products was one of the areas that were pursued very rigorously.

Secondly, when we started analyzing the hydrodynamic cavitation phenomena theoretically, we realized that it is also capable of bringing about certain chemical changes such as, when the cavity collapses, the temperature inside the cavity reaches 5000 to 10,000 K, as a result of which, the water vapour which is enclosed within this vapour cavity gets dissociated into H and OH radicals. The OH radical being an extremely strong oxidizing radical, this process has multiple applications. If you have hydrophobic moieties that get accumulated on the collapsing cavity at the gas-liquid interface, they get immediately oxidized due to the OH radicals being produced during the process. Thus, this process can be effectively used for effluent treatment thereby reducing water pollution.

Similarly, the shock wave that is generated, produces extremely high interfacial areas. So, emulsification is also possible. Thus, cavitation can be used for cell disruption, effluent treatment and for increasing the interfacial area wherever the mass transfer limitations are possible.

The next application that we realized was that during cavitation, because of the high temperatures, the solvent gets vaporized. When the solvent gets vaporized, the dissolved salt in the solvent takes the form of nuclei. So, the external seeding can be completely avoided for those crystallization operations, where external seeding or nucleation is required. The saturated mother liquor is irradiated with ultrasound or pass it through hydrodynamic cavitating conditions to generate in situ seeds or nuclei and allow them to grow. This allows us to have a controlled size distribution of crystallization.

Similarly, if instead of water, we have any other species in the collapsing cavity, the dissociation reactions generate several other free radicals. So, many of the reactions based on radical based mechanisms can also be carried out using cavitating conditions. The reactions can be intensified or facilitated using cavitation.

Scientists have attempted two other things which are still in their infancy. One of the things that they claim, but has not been proven yet is that it is also possible to use cavitation for nuclear fusion because pressures of hundreds of thousands of bar are generated during the collapse of the cavity. These pressures may be capable of fusing the atoms which can initiate nuclear fusion. Another application that chemical engineers are exploiting is that, since this entire phenomenon happens over a very small time scale, where we don’t allow the equilibrium to get established, it is also possible to break an azeotropic mixture. When vapour gets formed from a binary mixture, the vapour is in equilibrium with the liquid. But during cavitation, the vapour is formed so fast that there is no mass transfer and so, thermodynamic equilibrium is not allowed to be established. Thus, it is likely that the solvent having more vapour pressure will be enriched. Once the azeotropic limitations are overcome, it is also possible to use hydrodynamic cavitation to break an azeotrope without using an entrainer.

4. Your research also focusses on the use of Sonochemistry and Cavitation to reduce the size of substances to the nanoscale. Will nanonization and nano-sized products be the next revolution in the chemical and allied fields?

Nanotechnology uses the production of nano-sized products using two approaches, either the top-down approach or the bottom-up approach.

We start with larger particles and we keep using cavitation which produces shock waves and impaction to keep on reducing particles to a smaller and smaller size. This is called as cavitational milling, similar to the other types milling. Here without the use of hammer mill or bead mill, the size of particles can be reduced using cavitation. This is the top-down approach, wherein we start with larger particles and keep on reducing the size of the particles till it reaches the nano size.

In the case of a bottom-up approach, nuclei are generated using cavitation as described earlier. The nuclei generated during the collapse of the cavity, are typically 2-8 nm in

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size. Using thermodynamic calculations and by controlling the dynamics of formation of the cavity, we can calculate the size of the nuclei generated. The nuclei are then allowed to grow to the desired size. Thus, we need to have control of the cavitating conditions. One of the banes of cavitation is that being a stochastic (random) phenomena, it is extremely difficult to have control over the entire operation. To have control over the operation, the complete dynamics of the cavity have to be understood: how the cavity is generated, how it grows, how it collapses and what are the conditions under which it collapses. So once we start developing this kind of understanding, it can be exploited for multiple applications.

According to me, in case of industrial-scale production of nanoparticles, cavitation is going to play a huge role in the years to come.

5. What are some advantages of these nano-sized products?

It has been observed that nanoparticles significantly differ in terms of their bulk property. Due to their nano size, they are significantly different in their physio-mechanical and chemical behaviour. As a result of this, the bulk properties may be different but the same product is made available in the nano form and that too in different shapes of nano-sized particles: flat sheets, rods or spherical particles. It is possible that each of these shapes, because of their surface plasmon effects, may have different properties. Thus, exploiting the same material for a variety of different properties will be the key feature of nanotechnology.

We see beautiful butterflies with various colours. It is a well-accepted fact now that these butterflies produce these colours, just by changing the morphology of these nano-sized particles. If you would have tried to catch a butterfly some time, you would have seen that the pigment from the butterfly sticks on your finger for some time and it is extremely difficult to remove that pigment. The main reason for this is that these pigments contain nano-sized particles which are capable of entering the skin. Once it enters the skin, it can bring about various changes.

In fact, all our ancient manuscripts involving Ayurvedic or Homeopathic medical treatments essentially relied on the production of nano-sized particles. Some publications that have conclusively proved that the method that was used by our ancient Ayurvedic, as well as Homeopathic practitioners, were responsible for producing nano-sized particles and these particles were responsible for bringing about a change in the metabolite activity or the activity of a cell just by their sheer presence. This is how Ayurvedic and Homeopathic practitioners used it for the treatment of diseases and ailments.

6. Indian institutes of higher education with the exception of a few have low research and innovation outputs. What do you think is the problem and what are the possible solutions?

The scenario of higher education in India has become a catch-22 situation. It is like asking, what comes first, the chicken or the egg? In India, the funding that the institutes of higher education get depends upon the cutting-edge research happening in that institution. What research is at the "cutting-edge" in a particular field is essentially decided by the people working in that field, outside India. So, we tend to do research in that particular area because it is a problem that has been identified by somebody from outside India. That problem may not have any relevance in the Indian context. But unless an institution does that kind of research, it does not get funding. The funding agencies decide how modern the research is because the general sense of perception of these people who assess the research is that "there is no point of going back and reinventing the wheel." As a result, institutes do not get funding for conventional research. If there is no funding for conventional research, the researchers have no incentives to do such research and the whole vicious cycle continues. But it necessary for you to generate sufficient courage after you have established yourself.

If you look at me, I started looking at things which are of social relevance only after I established myself as an expert in the field of hydrodynamic cavitation. So, I created a completely new branch of chemical engineering and after

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2000, as I said, people accepted that hydrodynamic cavitation can be effectively utilized. From two publications, now there are thousands of publications which have appeared in this subject. So, once you realize you have established yourself, then you have time. After this, whatever you say, people are going to listen to you. However ridiculous it may have sounded earlier, it will not sound ridiculous now because now it is coming from someone reputed in the field. So when you have those sort of credentials, which require initial work to be carried out, then you can devote your time for solving social problems. When you see somebody get into something like this, then it also acts as a motivation for younger people.

I think it is extremely important for every established scientist or academician to identify problems of relevance for our country as well as of social relevance and then at least devote some fraction of his/her time to solve these problems. It is not that there is no science in these problems. There is definitely some science in these problems, but the way you approached the problem sometime in the past may not have been scientific. Once you have established your scientific base and credibility, whatever you do, will be based on the basic sciences. Once everyone follows this, I am sure that Indian academia has enough talent and expertise to solve each of those problems. It just requires a coherent effort, collectively being made by all the institutions of higher education.

7. Much of the research published today is inaccessible to the researchers, students and the general public due to paywalls set up by the publishers. Costly subscriptions have to be bought by institutions for their students. Do you think that this is slowing down the rate at which scientific discoveries and breakthroughs are made? Should open access be the norm?

There is a considerable debate going on in this area. Various governments all over the world, including the Indian government, are saying that, since the research is being carried out by using funds provided by government agencies, the research should be accessible to everyone. The governments of the countries are funding the research and they say, they do not mind paying for the open access journals as well because once the paper appears in the open-access journal, it is accessible to everybody. Why should somebody else make money, out of the research results generated using money provided by the government?

So, I am expecting that in 5 to 7 years, everything will be published in open access journals and the expenses which are incurred from publishing in these open access journals will also be in-built in the project funding.

I was associated, right from the beginning with a journal called Ultrasonic Sonochemistry. I have my publication in the very first issue of this journal. Till December 2020, this journal was a regular journal but from January 2021, it is going to be an open-access journal. There are going to be huge charges to publish articles in this journal and I don't feel comfortable paying such huge fees. I will not be able to contribute articles to this journal, though my group and I have contributed more than 200 articles to this journal. Now, if I want to publish an article in this journal, I may have to shell out $900 - $1500. I cannot afford this. Only when government norms change and the government diktats are issued, saying that the funding has been provided by the government, so whatever is published should be accessible to all, I am sure things will change for a better future.

8. What are some things you think ICT lacks or lags in, that you would like to improve?

I think the first thing that should be improved, is the attitude. The chalta hai attitude will not work. There is a place for the jugaad of course, but unless that jugaad is analyzed scientifically from the first principles, but it cannot be scaled up. Jugaad is fine for an immediate solution to a problem when you know that you are in a position to get over the bottleneck which you are facing currently, as a result of which, you initially get away. But once you know that this solution is possible, you must go back and look at that solution form a basic science point of view. Then only will the solution become scalable and sustainable. Jugaad solutions cannot be scaled up and sustained because it is just solving an immediate problem which you encounter.

Secondly, as I already said, you need to choose research problems which are of relevance. You always start your research career with curiosity and inquisitiveness. You want to learn why and how something is the way it is. By this you learn more, then you carry out research and finally you develop something new. Subsequently, you should also look at the possibility that, once you have developed that critical understanding of looking at a particular phenomenon, start observing your surroundings and learn from nature and the society, what problems require solutions. Be observant of your environment, surroundings and society. Problems are not going to be listed out in books as we study books and try to solve the problems at the end of the chapter. That is not real learning, but a kind of a skill set which you are developing. The real learning comes when you use the things which you have learnt to contribute and solve a problem. These are the only two basic principles that are required.

Thirdly, when you advance in terms of realizational understanding of science, do not forget the basics because we find that when we conduct interviews for PhD admissions or jobs, we find that the people who have done their masters or PhDs talk very eloquently about the research that they have carried out during their masters and PhD. But they fumble to answer the basic or fundamental questions taught at the undergraduate level. There is a saying in Marathi, pudhcha paath maagcha sapat (पुढच् पाठ मागच् सपाट) which means you learn more, but while doing so, you forget the basics. You cannot afford to forget the basics as they make you think innovatively and come up with the products and the solutions.

9. Please tell us about some of your innovative projects that are currently underway.

I think each of my students is working on some project. So, what I have done as far as my PhD and master students are concerned is that I don't impose my idea on them. So always at the start, I put up three or four projects which are of my interest but I never force these projects on the students. I ask my students if they are interested in doing something and help them in finding out, what they are interested in.

There are many projects related to cavitation, its applications and design of multiphase reactors. Some of these are essentially incrementally additive to the previous projects. Some are projects which are completely novel in terms of what are the products or processes that can come about. So, it is very difficult to give these short examples, but each of the projects I am working on is in my opinion of some relevance to the country. I have stopped working on problems which are esoteric in nature or blue-sky research. I only think about the blue sky research and come up with the ideas, but unless I have established at least one application of the results of the blue sky research, I don't enter into that particular field. So, you will find that each of my projects has social relevance attached to it and at the same time, it also has a lot of science associated with it, so that you can publish it. At the same time, since you have decided and worked on it with an application in mind, that application also helps you to exploit that research for the good of the society.

10. Undoubtedly, you are one of the best researchers ICT has ever seen and also an inspiration to many budding researchers. What advice would you like to give to them?

I would say, I am one of the many good researchers that ICT has seen- Prof. Sharma, Prof. Joshi, and Prof. Venkataraman. All these have been brilliant researchers and they have worked under extreme difficulties and constraints. That way, ICT is much richer as compared to what the situation was, earlier. When I did my PhD from ICT, I did not purchase a piece of single new equipment. I used to purchase equipments which were used earlier by somebody else or do the "jugaad" and then develop the equipments which were necessary for my research. Today, the situation is completely different. A PhD student comes and asks for the equipment, he needs. They do not make them on their own and want it purchased from outside. This

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situation should change, because it is killing the innovative spirit or ability of the student as that innovation is carried out by somebody else rather than the student doing it himself/herself. Sitting on a computer and doing numerical simulations is good, but ultimately it needs to be validated by hard experiments. You need to learn to fabricate, put up, run and modify the setup of these experiments. You will only arrive at these innovations only when you are developing hands-on experience to run these setups.