Introduction to Research
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Lecture - 39
Research in Metallurgical & Materials Engineering

Prof. Prathap Haridoss: Hello and welcome to Prof. B. S. Murty, who is joining us here today for discussion on Metallurgical and Materials Engineering. Prof. Murty is the head of our Department of Metallurgical and Materials Engineering, here at IIT, Madras. He is a highly decorated metallurgist, has won many national awards including the Shanthi Swarup Bhatnagar Award, and he is also the fellow of several national academies and also in many international organizations. So, he is imminently qualified to discuss research and what happens in the research setting, what students undergo and what experiences they have in the materials domain and his areas of research included high entropy alloys, bulk metallic glasses and so on. So, with these words of introductions, I welcome you to this interview.

Prof. B. S. Murty: Thank you, Prathap.

Prof. Prathap Haridoss: Yeah, thanks. What would you think our traditional areas of Materials science and Engineering that students are likely to see?

Prof. B. S. Murty: Our department originally started in 59, along with the IIT, Madras as the Department of Metallurgy. So, basically looking at traditional metallurgy, when I said traditional metallurgy, our department particularly concentrated on what is called Casting, Forming, Welding these are the 3 core areas of our department. Not, too much into the extractive metallurgy part of it, though there were few experts in that area too, but that has not been real strength of our department. Particularly, because there are not too many steel plants in and around Chennai okay and that has been mostly the strength of places like IIT, Kharagpur which has been very close to so many steel plants. So, as a result our department traditionally concentrated on as I told Forming, metal forming, how materials deform and then Casting of them because there are quite a number of

foundries in and around Chennai and also what is called Welding okay, there is for example; a Welding Research Institute in Trichy, which used to tie up with the IIT, Madras metallurgy department to a large extent, L&T use to have a lot of tie ups. So, welding which is a part of the manufacturing. So, if you can say the 3 major manufacturing processes which are Casting, Welding and Forming have been the core of our department traditionally for many, many years.

Prof. Prathap Haridoss: Okay so, I think may be the, see, the general audience including aspiring researchers may not be fully aware. So, when you talk of traditional areas like Welding, Casting and Forming, how relevant is research in these seemingly you know old areas relevant today?

Prof. B. S. Murty: For example, I take one example of welding you know, there is enormous research that is going on in welding, on for example, one of the major problems in typical traditional welding which involves let us say, you melt 2 pieces at the joint and then join them, that can give you a lot of I would say weakness at the weld joined because of the melting and the casting that is involved during this solidification process. And, there are a number of applications were you are not allowed to, for the joint to be exposed to very height temperatures. So, there is something called solid state welding that has come up in recent times. So, people are also working on friction welding, friction stir welding. So, where there is no chance of the 2 pieces, weld pieces being you know melted at all and as the result in the solid state they join and they retain a number of properties of these materials, which is very essential for the component to perform in the applications. So, as a result solid state welding has taken up.

Similarly, Joining is no more a simple welding process; people are now joining polymers with metals okay, polymers with ceramics, metals with ceramics. So, there is enormous research area in that okay. Similarly, now if I take forming as an area, there are new forming technologies that have come up, for example, Hydro forming, Sheet metal forming has taken up big you know straights in recent times, for trying to get the whole for example, if I take automotive car body, these people want to have the whole car body made up of 1 single sheet, instead of simply welding and joining a number of pieces.

So, there are technologies that have come up, where there is a lot of research has to go in to develop, what is called Stretchability inside the material and there is a lot of physical metallurgy also goes in, how to develop such stretchability into metals? What kind of new type of alloys have to be developed to have a high stretchability? So, forming also including new area what is called severe plastic deformation that has come in, where people want to generate ultra fine grain sizes inside the material by severely deforming these materials and use that for various applications in terms of enhancement of properties. So, in each of these areas there is a lot of work that is going on, for example; simple thing like Casting. People are now developing what are called Metal foams.

Prof. Prathap Haridoss: Ok.

Prof. B. S. Murty: Which are very useful for; this also a traditional casting process, excepting that you add some foaming agents to develop these foams. And, there the whole technology of how to develop uniformly distributed cells is a big challenge and there people are using newer technology such as X-ray Tomography to actually see the whole foam in 3D and try to design the foam in such a way that you get the proper properties. So, in each of these areas in fact, for example, people are looking at the casting as the solidification takes place. What kind of stresses are developed in the casting using neutron diffraction? I am trying to see whether I can do something to suppress what is called heart tearing? Heart tearing is the major problem in engine blocks and pistons and things like that. When people are developing, there are problems that people encounter during the solidification because of the stresses that are developed. So, people are using modern techniques to study them and trying to identify, how do I control it?

Prof. Prathap Haridoss: Okay So so, I mean the terms for these technologies for these areas of research may look traditional and ancient.

Prof. B. S. Murty: Correct.

Prof. Prathap Haridoss: But, really there is lot of modern activities,

Prof. B. S. Murty: Really, there are lots of modern activities.

Prof. Prathap Haridoss: And lot of challenges in these areas.

Prof. B. S. Murty: Lot of challenges in each of these areas.

Prof. Prathap Haridoss: Okay so, of course, materials is a very large field and then it virtually every field of engineering has materials in it. In recent times, what has been new areas that people have focused on, interesting areas that have come up recently that large groups are working on?

Prof. B. S. Murty: Yes.

Prof. Prathap Haridoss: Ok.

Prof. B. S. Murty: As you rightly side, I always tell people materials is the backbone of everything, without materials you cannot have anything. In fact, I say everything in this world is either spiritual or material. So, to that extent materials are that important. And when we say, as I was telling you we started the journey in our department as a traditional metallurgy and then around 2003, we realize that the non-metallic materials are also equally important, not only the metals. So, we introduced ceramics, polymers, composites everything into our curriculum. In fact, we even changed the name of the department in 2003 to Department of Metallurgical Materials Engineering which is what now the department is named after.

So so, in that connection a lot of newer areas for example, Electronic materials, Polymers, Composites, when I say Composite it would be Polymer matrix composites, Metal matrix composites, Ceramic matrix composites, Ceramics - high temperature ceramics. So, if I now look at the composition of my department, half of the department faculty members work on non-metallic materials areas and as a result materials such as, biomaterials, nanomaterials okay; variety of nanomaterials including carbon nanotubes which you yourself work on. And, materials which are for extremely high temperature

environments, for example, something like nose cones of a missile okay. So, you need materials for which can stand extremely high temperatures.

Similarly, various coatings for high temperature applications people are developing, you just mentioned about high entropy alive, people are trying to develop them as coating materials on super alloys, so that it gives additional high temperature capabilities for super alloys. Like this a number of newer areas, for example, electronic materials - quite a number of people in our department are working on that. So, after electronic materials, for example, thin films, semi conducting materials and magnetic materials. So, you name every material, now we have people working on these things and they have really taken almost equal importance to traditional metallurgy area that, if I look at the composition of the department is more or less you know, balanced in terms of modern materials and traditional metallurgy.

Prof. Prathap Haridoss: Very nice. So, that gives us also an overview of what sort of you know industries are looking for these kinds of things and where people may be able to you know, take their experience here to some setting were these kinds of things are necessary. So, of course, you are yourself a very successful researcher, very well decorated researcher and so on. And, there are many you know if you look at you do some general reading, there are lot of criteria people used to say that so and so has done well in research and so on. But, forgetting setting aside numbers, in your view in what way would you measure success in research?

Prof. B. S. Murty: Yeah, I would say anyone who can make an impact on either an industry or the future researchers, is what I would consider it as a success. That, the work that you have been doing, has it being really bringing newer technologies, newer process, newer materials which an industry is able to use and make itself as a leading industry in the Global Arena is one way of looking at success or the other way is your research has kind of nucleated a number of other researches okay, which people have taken up a queue from your research and started working on that and taking it forward, this is another way of looking at it. So, basically it all depends on what kind of an impact that you are making either on the industry or on the research.

Prof. Prathap Haridoss: Ok.

Prof. B. S. Murty: Of course, people use numbers as a way of looking at it, but not always numbers are important. Among the numbers, which are the ones which have made more impact on the society of course, it's also important when we talk about in this context. Has it also made an impact on the general you know development of the country in terms of the societal needs?

Prof. Prathap Haridoss: Societal needs.

Prof. B. S. Murty: So, that's also very important. Rural development areas, the number of newer materials that are being developed which are being used for certain applications in even agriculture, so that we grow better. So, these are all the things which are, I would say the matrix people should use.

Prof. Prathap Haridoss: Should used to gauge how.

Prof. B. S. Murty: In my view.

Prof. Prathap Haridoss: Okay very nice. So, if we step back and we have new students who are coming from various backgrounds and who joined research programs in you know various institutions across the country, they are moving away from college education, undergraduate education to postgraduate education and so on. In your view, what are the typical kinds of challenges such student face especially, let's say coming into a materials kind of a department?

Prof. B. S. Murty: Correct. The basic difference between an under graduate education where you are kind of coached okay to study some material or certain reading material and then you go through certain exams and then gets certain grades out of it. To research is the basic difference comes is the, where you try to independently do most of the things yourself. So, PhD is a training ground where we train people, how to plan a certain work and execute it, analyze what comes out of it and then bring out some logical conclusions

out of it. All these things has to be inculcated in a particular student, which most of the students who come from the undergraduate education are not really trained on that. And, also particularly materials research needs handling a number of instruments.

Of course, there is a lot of computational research that also goes on in materials. For example, the new buzzword now is called ICME; Integrated Computational Materials Engineering the people call it as. Starting what people, starting from the atomic level to the macro level can we connect everything, what people call it has multi skill modeling. So, there are people who are trying to do that. There also, many people might have learnt software as a software per se. But, not utilizing the software for solving certain problems, real like problems that posses a lot of challenge when a student actually comes into research. This is one aspect.

Second aspect is in the experimental work, where handling various equipment okay For example, making materials itself is a major challenge and that has to be made in certain condition so that, there is a reproducibility that is essential in any scientific research. So, that is another thing that has to be trained by the faculty and the senior students to the newly joined student. And also, handling various characterizing facilities, just by making a material as simple as I can tell you, anybody can easily make a nanomaterial nowadays. But, to prove to somebody that you have made a nanomaterial is not so easy, it needs various microscope which are extremely expensive starting from anywhere ranging from about 1 crore. It can go up to almost like about 17 crores, we recently have bought a microscope in our Institute which costed us almost like 17 crores, where it can go up to 1 angstrom resolution.

So, you would like to see these materials at that level and that needs a lot of training. So, we have a number of these training programs. For example, we have a course which is called Practical Transmission Electron Microscopy Course. Where, one full semester the student goes through, how to handle this such a sophisticated instrument? Starting from, how to prepare a sample for that instrument to the last day where he will demonstrate good micro structure from such a microscope to be able to you know make himself you know eligible to handle such kind of sophisticated instruments, all these need to be trained. So, that is why the whole 3 or 4 or 5 years, the time that is the students spends

here, for either an MS program or a PhD program is basically towards this kind of training. So, these are the challenges. Of course, they look as challenges when you start with, but there is a lot of enjoyment in learning all these.

Prof. Prathap Haridoss: Lot of opportunities.

Prof. B. S. Murty: Lot of opportunity.

Prof. Prathap Haridoss: Yeah, yeah.

Prof. B. S. Murty: Lot of enjoyment when you do it and when you learn many of these new techniques, they are going to be of a great use when you go for a post doctoral research later where, you are supposed to do a independent research and then also when you yourself become a faculty member to guide the next generation students. All these training will be of a great use.

Prof. Prathap Haridoss: In fact, yes in along those lines. So, what sort of positions did you typically see post graduate students, people completing MS and PhD from our department? What sort of positions did you typically see them going towards?

Prof. B. S. Murty: Typically, the majority of the positions I would say are academic positions, faculty members in various now. In fact, that opportunity has significantly grown, if you look at it, once upon a time there were just 5 IIT's now, there are almost more than 20 IIT's, possibly a number of 23 or so. I do not exactly know the correct number, but something around that.

Prof. Prathap Haridoss: Yes.

Prof. B. S. Murty: And then, NIT's. You have about 1 NIT for each state. I heard that, there are about 30 NIT's and a number of private you know academic institutions. Which are also of reasonably good standard are coming up. In fact, some of them are taking up faculty, who are being called as research faculty, they don’t need to even teach, they

simply their job is to keep on doing research, get projects, to publish paper so that their visibility in the research arena is grown. So, this is one spectrum which has grown to a big level that the opportunities for PhD students into those have significantly grown. This is one.

Second is, earlier the industry never used to really take a number of PhD students, they say B. Tech is good enough for us. But, it is now you see quite a number of industries are taking research scholars, I mean people with an MS or PhD background, particularly because they would like to compete globally and become a global leaders. For example, in Chennai itself if you look at it Mahindra and Mahindra have set up a big R&D center, where they are looking for people with the research background. Similarly, a number of Multinational R&D Institutions have come up for example, GE has their own set up in Bangalore, who are taking a large number of materials people with materials background with MS or PhD. Including even Tata steel, every year he is taking a number of people with a PhD background so, for their own R&D. So, the industrial R&D is picking up in a big way.

Prof. Prathap Haridoss: Ok.

Prof. B. S. Murty: Thanks to what we call it as make in India.

Prof. Prathap Haridoss: Make in India movement.

Prof. B. S. Murty: With that movement, a lot of industries are trying to make their products globally competitive and not only globally competitive they would like to be global leaders.

Prof. Prathap Haridoss: Ok.

Prof. B. S. Murty: So, that is where research is very crucial and people with research background are able to fit themselves into such an environment and then grow much better.

Prof. Prathap Haridoss: Okay very nice. Now, let's supposing we step back a bit and look at the you know time that post graduate students spends here as a researcher through his you know degree program, a very mundane question, how often should such a student meet his adviser his or her adviser?

Prof. B. S. Murty: There cannot be a prescription for such a thing.

Prof. Prathap Haridoss: Sure, sure.

Prof. B. S. Murty: Ok, it depends on the student okay how capable he is to handle things on his own. It depends on the background the student comes from and depends on the problem that he is tackling.

Prof. Prathap Haridoss: Okay fine, fine.

Prof. B. S. Murty: If it's a very difficult problem, I would even suggest but, it also depends on whether you are in the beginning of your research or are you moving towards the fag end of your research, PhD degree or so. So, initially it is suggested that you meet almost on a weekly basis okay. So that, you are sure that you are on the right track and once you feel yes, you got a hold on the thing, that things are moving well and then possibly you know I would suggest at least once in a month.

Prof. Prathap Haridoss: At least.

Prof. B. S. Murty: If not frequent, more frequent than that.

Prof. Prathap Haridoss: More frequent than that, Ok.

Prof. B. S. Murty: I usually meet my students once in a fortnight.

Prof. Prathap Haridoss: Ok

Prof. B. S. Murty: So, once in a fortnight, I would an hour I spent with each of the student.

Prof. Prathap Haridoss: Each of the students.

Prof. B. S. Murty: And, I tell them that if you have any other issues, you are free to come and meet me any time.

Prof. Prathap Haridoss: Ok.

Prof. B. S. Murty: But, I would suggest that initial days, it is more important to meet more frequently because the student is not used to you know, first of all planning things. In any research, if you don't plan anything properly ultimately, the result is not going to be as expected.

Prof. Prathap Haridoss: Ok.

Prof. B. S. Murty: So, as a result during the planning stage it is very essential that you are in touch with your guide a more frequently because his guidance becomes very useful in that initial period. Later, you are possibly able to guide yourself on your own.

Prof. Prathap Haridoss: Okay so, I would like to close with this question for you, what would your advice be to an aspiring student in Metallurgical and Materials Engineering?

Prof. B. S. Murty: Okay for that matter, any area if you are doing PhD whether it is metallurgy or not, you should first enjoy this is very important. I would always tell this for a research scholar you need to have 3 qualities okay, you should be able to go for a cup of coffee with your friends and discuss research, not a cricket match that has happen possible the previous day or so. And then, you should be able to go to bed thinking about the problem that you are trying to solve okay that basically means, you are involved in your research, you do not take a research as one of activities that you do on a daily basis. But, it is the activity for you, the most important activity.

Most importantly, I would say the third one is, you should be able to catch an youngster okay just joined in your group are possibly a 12th standard kid and make him excited about what you do. What is very important in research is, to be able to feel that you are possibly the first one to be working in that field, after all you know any research if you simply repeat what somebody else has done, you would not get a degree. So, every PhD student wherever he is, he is working on a problem which possibly nobody else is working on, at least a particular facet of a problem, which he is uniquely trying to develop a solution for that. So, he should feel excited that he is the only one who is working on that and that excitement in research is very essential, if you do not retain that excitement and that fire in you obviously, research is not enjoyable and if you don't enjoy a research there is no point in doing research.

Prof. Prathap Haridoss: So, involvement and enjoyment.

Prof. B. S. Murty: Yes, are very essential.

Prof. Prathap Haridoss: Thank you so much for joining us, they were useful one.

Prof. B. S. Murty: Thank you. Thank you.