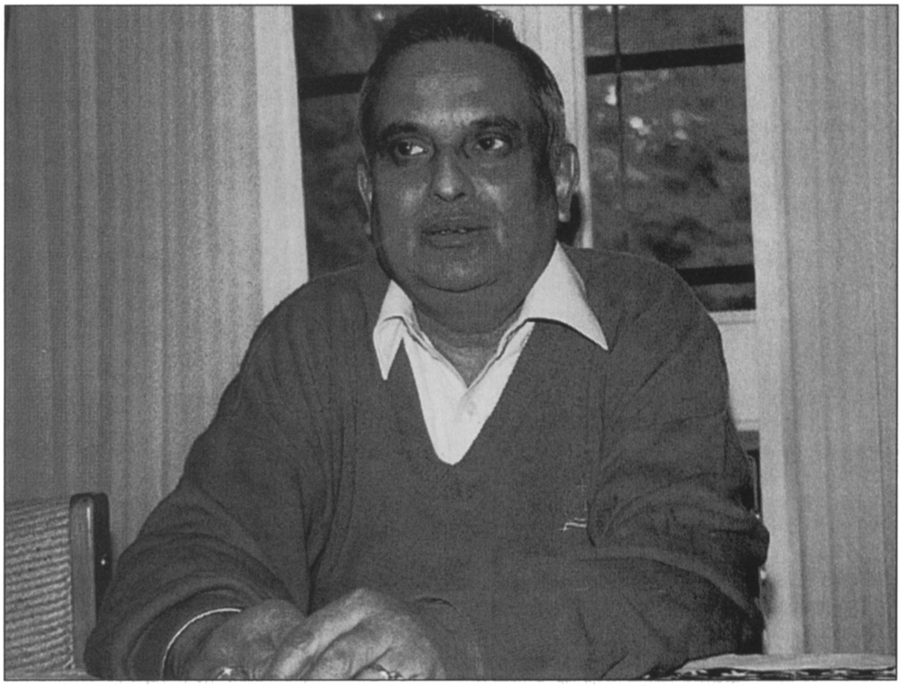
A Passage From India: A Conversation With P. Rama Rao



Prof. Rama Rao rarely travels outside of India. MRS Bulletin *tracked him last month in the United States where he attended a conference and was on a short holiday, the first one, it seems, for over a decade. For scientists and technologists in India, Prof. Rama Rao needs no introduction. For decades, he has been an outstanding researcher in materials, was a top government administrator of science and technology, a distinguished professor of metal sciences in Banaras Hindu University, and was, until recently, the President of the Indian Academy of Sciences and of the Materials Research Society of India (MRS-I). This year he presided over the largest annual gathering of scientists and technologists in India, The Science Congress, that attracted more than 7,000 delegates. He is also one of the very few foreign fellows of The Royal Academy of Engineering of the United Kingdom.* MRS Bulletin *was keen to meet and talk with Prof. Rama Rao to learn what prompted him and his fellow materials scientists in India to form MRS-India; and more generally, we wanted to know what he sees as the role for materials scientists and technologists in society.*

When we first planned our interview, our many Indian friends warned us of Rama Rao's modesty and self-effacement, and how it could preclude our drawing him out in conversation. We need not have worried. When we first met him at his friend's home in Pittsburgh and later at the MRS Bulletin *office, Rama Rao spoke freely and was ready with his speculations on where materials science was heading. Rama Rao speaks slowly and deliberately with an enviable command of the language and subject. Years in government have not muted the academic in him. When we talked of his research interests, his eyes lighted up with a rush of words, sharing with us his latest excitement of developing a very strong and tough engineering alloy. But we wanted to go back to what first turned him on to materials:*

What turned you onto science or metallurgy in the first place?

In my case, I actually stumbled into metallurgy. I'm basically a physicist. One of my class fellows in the Physics Honors course decided to pursue metallurgy at the Indian Institute of Science, Bangalore. For me he was a role model, and so I followed him to the Indian Institute. Having been accepted into the Institute, I found I liked the subject very much. Also at the Institute, I held a teaching position in the metallurgy group where I taught x-ray diffraction and physics of metals to metallurgy students. My physics background was very useful in teaching these courses. As time went by, I learned that metallurgy is a discipline that derives so much from basic sciences, and later I also saw its impact on technology as well. Metallurgy, as thus, is a unique discipline which is really not one discipline, but has connections everywhere.

Do you mean that materials science is not a distinct science but is in the eye of the beholder—physics, chemistry, mechanical engineering, and so on?

No, materials science has become a distinct science now. The uniqueness comes from various sciences dealing with several materials and not just one material or a metal. Now materials science has its own mission.

What gives it its uniqueness? Why is it so important to be a discipline?

The uniqueness of the materials discipline comes from having principles in place that are common and have wide applications. Structure-property relationships, for instance, are important in all classes of materials. What we learn from one type of material is applicable to others as well. Take ceramics and metals, for instance. They have a common structural basis. You strengthen metals through phase transformation, especially so in steels. In ceramics we use transformations to toughen the material. Transformation thus strengthens weak solids like metals, while toughening strong solids like ceramics. But the principle of transformation remains the same.

Profiles & Perspectives explores the people behind the profession of materials research.

Don't you think that materials science is also unique in its closeness to technology and products, that is, the speed with which it is able to bring technology and products to the market place, unlike, say, in physics or chemistry?

Very true, and this actually provided us the motivation to set up the Materials Research Society of India (MRS-I). We have societies in India for metallurgists, physicists, and chemists, for example. The stimulus for setting up MRS-I was to bring people working in various disciplines together for a common mission: materials. The scope is large: all the way from basic sciences to applications. One can easily see the importance of basic sciences: chemistry is important to our understanding of materials synthesis; physics, to our understanding of properties. But when we move on to applications, we see the importance of design and technology.

An example that comes into mind is a development in the materials field that has had a major impact. Superconductors have captured everybody's imagination—levitating trains, energy storage—but I am not talking about those, but about the development of a certain class of magnetic materials. There was a technological breakthrough a few decades back, when samarium cobalt magnets were developed, with the magnetic energy product jumping from 5 MGOe for Alnico magnets to almost 25 MGOe. With the new neodymium iron boron magnets, this value has reached a peak, to an unbelievable 60 MGOe. These high values by themselves don't mean much except for the changes they bring to the design and performance of products. The old microwave tubes used Alnico magnets that were large and heavy. But with the availability of rare earth magnets, the rules of design have changed. One can miniaturize these tubes, of course, taking care of other operating conditions. New traveling wave tubes (TWT) are really quaint and small.

For this to happen, the scientist working in the physics of magnetism would have to work closely with design engineers, and heat-transfer and microwave specialists. I believe the existence of a distinct discipline brings out such integration easily.

Tell us about Materials Research Society-India. Do you think MRS-I can be a leader, helping to share the excitement of new materials with a large audience? Or do you see it as a mere follower of where technology is going?

Materials Research Society of India had its 9th annual meeting in Chennai recently. But the zeroth meeting was at Hyderabad when we founded the Society at DMRL [Defense Metallurgical Laboratory in India]. Prof. C.N.R. Rao, an internationally known chemist, was the driving force for starting the Society. We are planning to celebrate the tenth anniversary next year. I see already that MRS-I is far more effective than other organizations in India in bringing together people who work in different disciplines. In Madras, we even had sessions sponsored by industry. One full session was devoted to building materials. More than mere sponsoring, industry also provided speakers. The keynote speaker was from industry. I see this to be a good trend with MRS-I, providing a common platform helping to integrate research with development and production. And we must allow the market forces to operate.

In your own research, I see a trend of taking materials to new designs and products. Yesterday [March 18, 1998] in your seminar you talked about the development of ultrahigh strength low-alloy steel and fabricating them into rocket cases.

I have been very fortunate to have had opportunities to see research and development leading to products. The Indian Defense Research and Development Organization provided me with such a base. Professionally, they were the most satisfying years. I was involved not only in the development of high-strength steel, but also others: for example, in the research and development of tungsten-heavy alloy projectiles for antitank ammunition. These alloys are made through powder metallurgy and it can be a difficult process. Working with an outstanding group at the Defense Laboratory (DMRL), we were able not only to develop the alloy and a product, but also to set up a totally automated production facility in which to manufacture them. This experience was a very good opportunity for me to appreciate how materials development takes place in the real world.

How far are we from designing materials such as steel from first principles?

I think it is still a long way off. Today we use first principles to improve the properties of existing compositions. Take, for instance, the problem of stress corrosion cracking in ultrahigh strength steels. We have to understand the properties of grain boundaries and the role they play in storing solutes and impurities. Recently, there has been some excellent fundamental work on understanding how solutes and impurities affect grain-boundary cohesion. There are also powerful tools to investigate grain-boundary segregation at atomic levels. We have to understand the atomistic and electronic mechanisms before we design new compositions immune to stress corrosion cracking. But designing a new composition from first principles is still some distance away.

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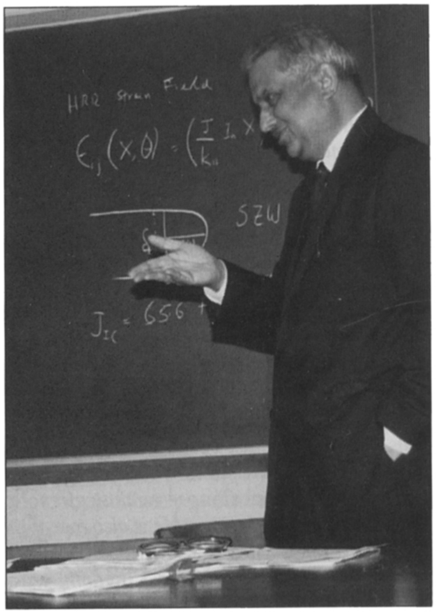
Is it because of the difficulty we have identifying unique microstructures with the composition and atomic bonds, or is it because of something more than that?

Why is this so? We simply don't have adequate data. Take, for instance, the phase diagrams. We have an excellent base of binary phase diagrams. Even in ternary diagrams, we leave out a number of combinations. But when we go on to a large multicomponent system such as alloy steels, we don't have the necessary basic data on thermochemical and thermophysical properties for all combinations. One has to resort to empiricism based on experience.



Materials scientists and engineers are so rarely seen or heard when designs and products are successful. Do you think they get recognized adequately? We talk of a rocket scientist, but not of a materials engineer!

My personal experience is that designers look to materials people when they have a problem or when they have a new product to design. But when the job is over, the materials person is not forgotten—there may be new designs needing newer materials—but he or she does not capture the limelight in the same way as designers do.

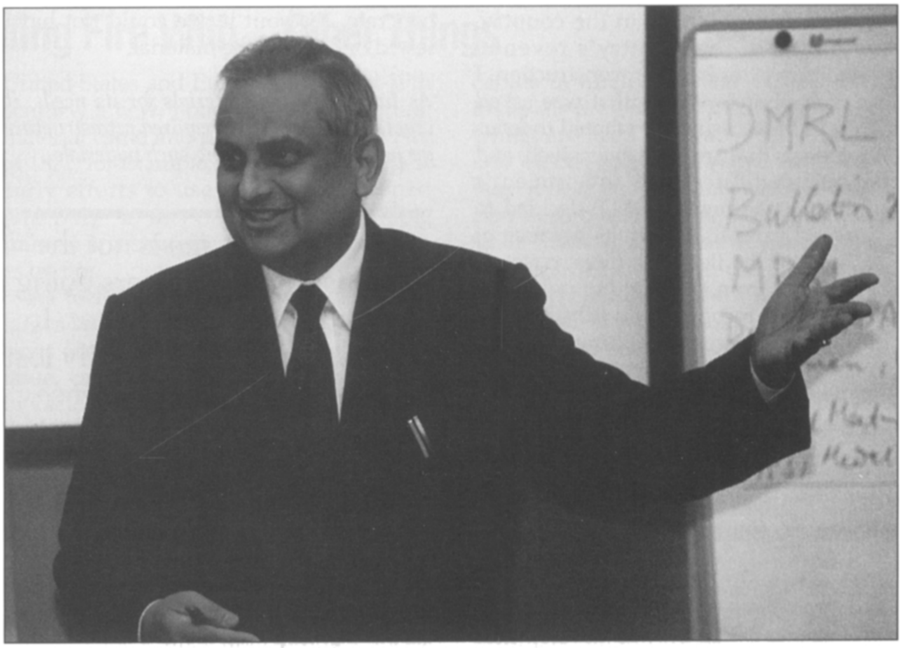
For example, because of its light weight, aluminum is a likely candidate for the design of lightweight automobiles. But aluminum, unlike steel, cannot be spot-welded. Today's assembly lines use spot-welding extensively. There was a real technology issue here. The problem has been solved with the use of a different joining technique like adhesive bonding. A new technology and its underlying basic principles have been added to the repertoire. But we take all these things so readily for granted and move on to the next system.

Why worry so much about recognition when the challenges themselves are exciting enough? I am now working in the Indian Atomic Energy Program and becoming familiar with problems of nuclear power. Everywhere in this technology I see the role played by materials scientists: from extracting uranium from ores as lean as 0.05% of metal to developing complex and difficult-to-fabricate alloys such as zircaloy. Even extracting zirconium and separating it from hafnium—a large neutron absorber—is a saga in itself.

When a materials person solves the problem, the design moves forward. And we take his contributions for granted. Ultimately, the power engineers take over the plant, as physicists and chemists dominate research laboratories. This is the way things are, and I don't think there is anything here to complain about.

I notice that you were a university professor. Do you see Indian universities playing a major role in materials research and development?

Yes, I'm a university man and am proud of Indian universities. I think universities generally excel in basic research. Any applied research in the Indian context continues to be difficult as our industries have still not come of age. And when people talk of universities in India earning their revenue through applied research, I am really worried. By asking this from our universities, we are imposing too high a burden on the university system.



People feel the same in this country [United States] as well.

This is just one aspect. I am more worried about support for basic research. India has some of the oldest metallurgy departments in the world. The metallurgy department of Banaras University, where I was a professor, was set up in 1923, well before Cambridge and Oxford set up their full-fledged departments for metallurgy. This department in time helped the formation of a school for materials technology. Some from the metallurgy department moved into the new school with physicists and chemists. This is the integration I was talking about.

How does the basic research then end up getting into engineering? Or does it reach there at all in India?

We are trying to solve the problem through a clear articulation of programs and forming development teams that integrate people from various disciplines. Some members of the teams can actually be from universities. For developing a new product based on a magnesium alloy, we depended on the Indian Institute of Science. Prof. Y.V.R.K. Prasad helped us by developing deformation processing maps for the compositions. We made use of the knowledge and expertise residing with his group.

This calls for a great deal of integration. Does it exist in India?

Yes, but only in high technology programs.

But I understand that it exists in your commercial sectors as well. Why is this pattern not practiced extensively in India?

I really don't understand the reason. Take our gem industry for instance. It is a large, very profitable and export-earning industry. People in this business are very enterprising. Yet, these people import from abroad all the raw materials they need for melting and alloying of gem compositions. This is in a country that has a large zirconia production for making zirconium and zircalloy nuclear fuel cladding tubes. When you really look into this issue, it turns out to be a problem of impurity removal. This should not really be a difficult task to a group that had done a relatively more difficult job of separating hafnium from zirconium. Yet this has not been done. The motivation when it comes to commercial sectors continues to be weak.

Going back to your own research career, you don't seem to have spent many years working outside India. Many from India either visit other developed countries frequently, or work in the West for extended periods. We don't see you very much here in the West. Do you think you have missed something by opting to stay in India, or has it been more satisfying to stay in your own country?

I might have been working in India, but not in isolation. I am fortunate to have so many friends and contacts in the West, and I have been in touch with many of them and collaborated with some of them. Some of my students are here in this country [United States] and they also keep me informed of the developments. When I became busy at home, there was so much to do and I simply could not afford the time for international travel. I was also fortunate to work at DMRL which is one of the well-equipped materials laboratories of the world. If needed, I could have added more facilities. The lack of experimental facilities was therefore not my problem. Perhaps if I had continued to work at the university where I spent my earlier research years, I could have encountered this problem. Having said this, of course, visits to laboratories in the West would have helped me professionally.

We come to a more familiar question, the so-called brain drain.

What bothers me is not the scientists and engineers going away to the United States. In my view they are not really lost to the profession. In a sense, they constitute a brain bank and not a brain drain. But what I worry about in India is the migration of scientists and engineers to management jobs and to software engineering. You may know that India has a very fast-growing software industry. These migrations, within the country, deplete the country's scientific human-pool significantly. I see this as more harmful to India, especially at a time when India needs more engineers and scientists for building its infrastructure.

I want to tell you an example of the kind of problems we face in the materials field in India. With the large amount of construction, building materials have

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become very important in the country. About 30% of the country's revenue expenditure is on building construction. I was chair of a committee that was asked to look into this issue. We wanted to focus on materials that are used extensively and also on substitutes. The government's building department (CPWD) decided to ban wood from its buildings because of the threat to the fledgling forest cover in the country. From the world of polymers, we wanted to recommend a substitute for wood for such standard things as door panels. But, then, there were no specifications available for these applications. How then can we substitute? It took us some time to develop those specifications. For conducting tests on wood substitutes we needed the test facilities. And only one laboratory, Central Building Research Institute at Roorkee, has these facilities. So when we went for applications, we encountered many bottlenecks. In India, the challenge is not only to develop new and appropriate materials, but to develop specifications and set up facilities for acceptance tests. Often such facilities that we take for granted in the West are not available in India. Sometime back, we developed a high-strength concrete to the standard of M60 grade. Certifying this material involved complex tests. Luckily, for an earlier program we set up such a testing facility in one of our laboratories. This facility came in handy for testing this concrete. Without it, we could not have tested or certified the material.

As India develops materials for its needs, it must also establish the required infrastructure for proving and certifying such materials.

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Yes. We have set up such an infrastructure for metals. But a similar infrastructure, be it related to semiconductors, ceramics, or polymers does not exist. Adjacent to DMRL we have set up a number of modern testing and certification laboratory for aeroengine alloys. But we don't have similar laboratories for other classes of materials in India.

What major materials issues will be addressed in the near future?

All along I have been talking about the importance of design and technology in materials. But there are many downstream issues that have to be addressed in the coming years. We shall be dealing more with materials recycling, waste management, and economy of energy usage. For India, we should add the additional area of building quality infrastructure for materials and component testing.

A last question. You have been a teacher, laboratory director, and a seniormost government official dealing with science and technology. Which one of these did you enjoy most?

Teaching. Undoubtedly it was teaching. Anytime I enter the campus of a university, my heart actually warms up. Yesterday, I spent some time at Carnegie Mellon University visiting laboratories and talking to faculty and students and this brought the memory of universities back to me. Teaching is what I have enjoyed most. But, then, I have learned so much being a director of a laboratory and seeing how the real world of industry and products operates. The opportunities I had at DMRL and the lessons I have learned all along were many. If anything, these experiences should make me a better teacher.

We then saw Rama Rao in a new light: not as a run-of-the-mill administrator, but a teacher. The gleam in his eyes said that all.

The interviewers were *MRS Bulletin* editor Betsy Fleischer and 1998 visiting scientist V.S. Arunachalam.

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