Advanced Materials '93, VI / Frontiers in
Materials Science and Engineering, edited by S. Sōmiya et al.
Trans. Mat. Res. Soc. Jpn., Volume 19B

Potential and Limitations of Materials Development and Application in the Automotive Industry

C. Razim

Mercedes-Benz AG, Stuttgart, Germany

On average, approx. 50% of the expenditure of the automotive industry is spent on materials. This includes all costs for processing the material including the cost of energy. This means that the material costs are far higher than any other costs, e.g. the cost of personnel. This results in the logical demand to reduce prime costs in materials engineering, too. These measures have so far been implemented with only consideration for technological and economic aspects.

In addition to technology and economy, ecology will have to be included in the considerations in the future. The input/output process of industrial production requires a greater or smaller amount of materials and energy, depending on the product and the production method applied. It inevitably causes residues and waste in the form of materials and energy. These materials can only be reduced to a certain extent requiring ever greater technical and financial expenditure. In addition, every recycling process needs energy, too. Therefore, the aim is to achieve an optimum solution with the relevant large-scale technology available. "100% recycling" of materials and energy will always remain unattainable.

Taking the saving of resources and recycling into consideration in the materials selection leads to conflicting targets of technology, economy and ecology. Optimum materials selction is then a very complex, four-dimensional problem.
Environmental issues must be integrated into new technologies, i.e. the only reasonable course is to prevent environment burdens right from the start instead of implementing "end of the pipe" solutions. The ecological aspect must enjoy the same priority as technology and economy.

Materials selection and the recycling concept at Mercedes-Benz will be explained to illustrate the integral environmental protection strategy.

The input/output process of industrial production requires a greater or smaller amount of materials and energy, depending on the product and the production method applied.

Figure 1 shows the process as it occurs in a normal production plant: on the one hand, as can be seen on the right-hand side, the input of the materials to be processed, the energy and the process materials required for production processes are presented.

However, as it is clear from the left-hand side of the figure, the results are not only the desired product, the actual objective, but also with other products - negative products in the sense of economy - which must be further processed, disposed of, or at least coped with. The necessity for coping with the residual materials and residual energy arising is already mentioned directly and indirectly in every environmental discussions. These concern ultimately the harmony between technology, economy and ecology, the conflicts which have to be taken into account in every technical process.

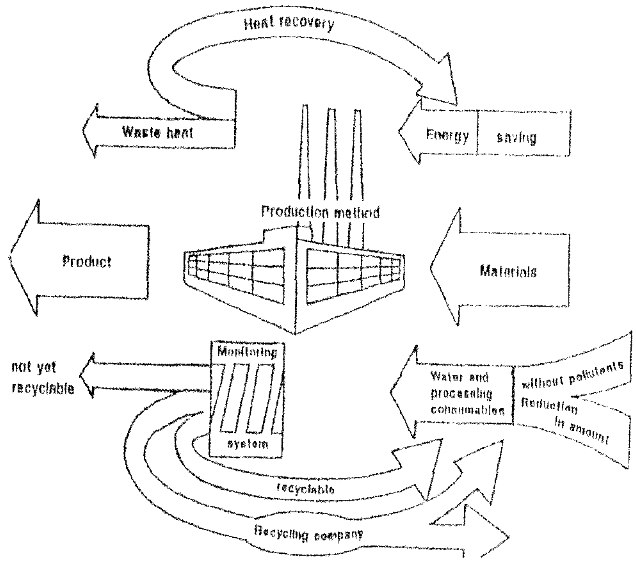


Figure 1: Material and energy flow in production companies

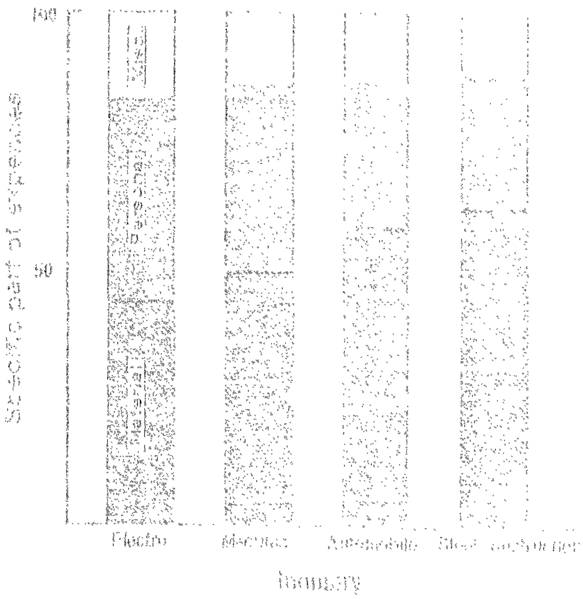


Figure 2: Distribution of expenses of industrial companies

The significance of the part played by the selection of materials in this framework is one major aspect of this paper. By way of introduction with regard to economics, this is clearly set out in **Figure 2** which illustrates the size of material costs referred to total expenditure in various branches of industry. These costs amount to around 50 %, and in the automotive industry specifically they compromise 50 %. Therefore it should apparently be worthwhile developing suitable strategies to make use of the high percentage of material costs as an unusual form of potential for rationalization, if only because rationalization cannot be achieved with such ease by other means. The expression "not with such ease" demonstrates that rationalization measures taken in the materials sector do not necessarily entail personnel reductions if it is possible to cut costs by adapting the material optimally to its intended purpose.

Figure 3 illustrates another economically important aspect, namely that manufacturing costs are several times greater than development costs.

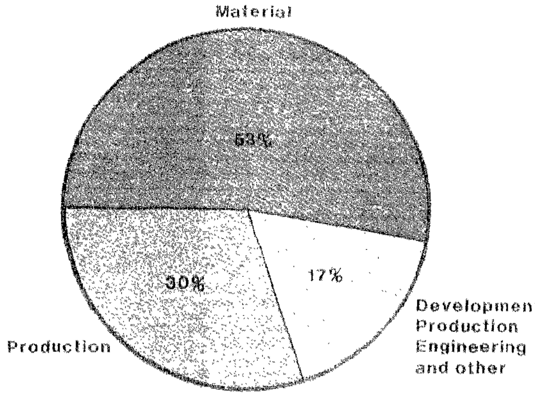


Figure 3: Breakdown of costs in the automotive industry: source Statistisches Bundesamt

This results a dilemma which affects more or less every industrial company: the responsibility for establishing the costs lies primarily, 70 % in fact, in development or design **(Figure 4)**. Production planning only accounts for 15 %. Although "miscellaneous" and purchases must not be neglected, they also add up to only 15 %. The dilemma, which is particularly crucial, must be resolved because at the end all considerations, strategies, rulings and suggestions given by the design department always take effect in terms of costs in the production. The costs arise in this field but are in fact caused by quite a different department altogether: indeed, by the design department! From a economic management point of view, this naturally leads to an unavoidable conflict of interests and responsibility.

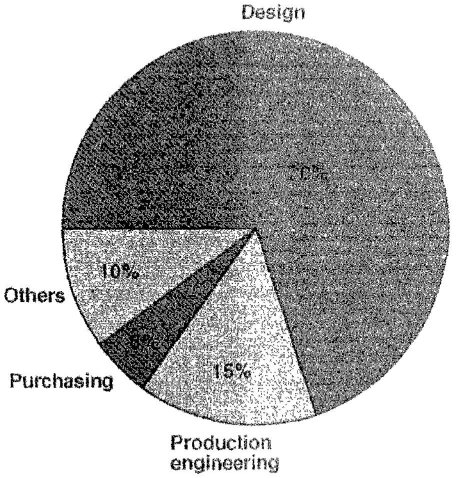


Figure 4: Cost responsibility within companies

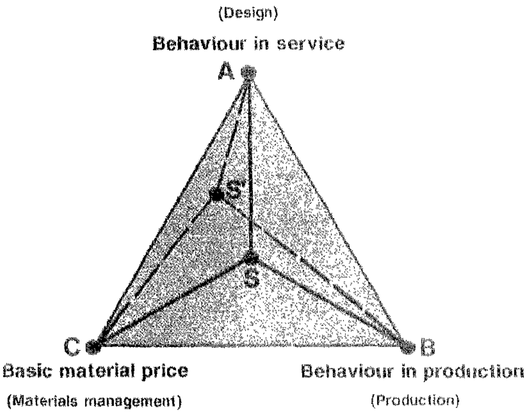


Fig. 5: Strategic triangle of industrial materials technology

For the development of generally valid criteria, the decision on correct selection of materials from an economic standpoint has to take into account at least three factors, as illustrated in **Figure 5**. The first factor is that the wishes of the designer, who must regard the guarantee of his product's performance should be fullfilled. It attaches a good deal of importance to it.

The second aspect is that the product's behavior during manufacturing - a matter that concerns the production engineer's cost-thinking - has an extremely strong influence on costs and is therefore a very important factor.

The third point is that the basic price of the material, which is dictated by the overall economic situation on the market, must be taken into account.

These three factors must be balanced out because this equilibrium is the only way to prevent neither one being overrated nor another neglected and to eliminate conflicts of interest between departments. The economic law which is typical for every company, is to strive for maximum profit by achieving an equilibrium in these three components.

This is the classic theory for the economic valuation of material's related decisions. But over and above that, in the last few years the material scientist has been confronted with an increasing number of additional problems and influencing factors, and this will probably become even more the case in the future.

This is demonstrated in **Figure 6**, which is based on an important variable, namely the energy consumed in the manufacture and use of a motor car component made of different materials, but of identical rigidity, over a distance of 100.000 km. Naturally it is a fictitious account because it is immediately apparent that of course a connecting rod in an internal combustion engine cannot be manufactured from zinc as has been theoretically assumed in this example here in order to take into account the "energy expenditure" as an important feature approximately. The level against which all others are measured is the steel component, and this is assumed to have the value 1.

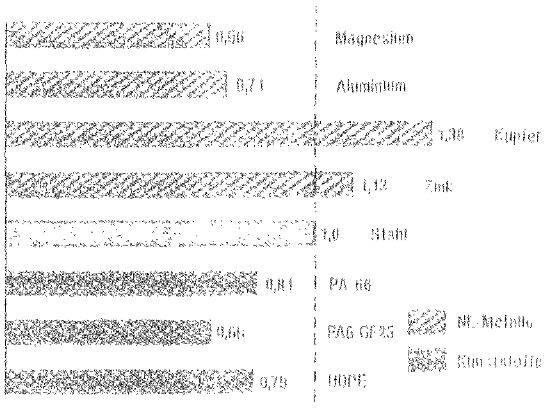
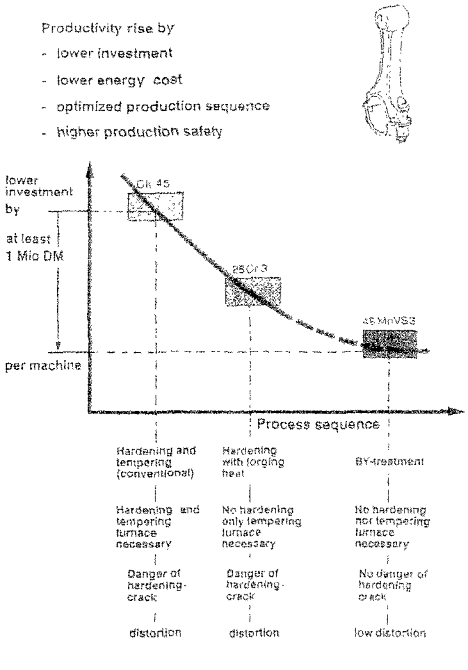


Figure 6: Energy required for production and use of a vehicle component of identical stiffness over a mileage of 100.000 km compared with the steel variant

Aluminium, for instance, or certain types of plastic come off very well from the point of view of the total energy expended. It must particularly be emphasized that this diagram omits the costs of manufacture, which will be taken into account using another example. Also there is no critical assessment of the component's behavior during use, linking with the statement, that a con-rod will hardly be manufactured from die-cast zinc.

The analysis of a material in its entirety is a job that will occupy an increasing amount of the engineer's time in the future, at which as the common yardstick of the three components will not be sufficient on its own for any final decision to be made. It is rather necessary to establish the connection between technology, economy and ecology. For this purpose, e.g. the actual situation within the group of steels must be considered in detail. Increases in productivity can be achieved by clever selection of materials. This may for instance lead to a situation where investments can be reduced or even avoided altogether and where considerable savings in energy costs can be made and last not least the product quality will be improved. **Figure 7** illustrates an example: the use of Ck 45 (identical with SAE 1045) as the classic variant. It requires conventional hardening with all the complications of high energy consumption, the danger of cracking during hardening and the high level of distortion, whilst with alternative - an example here is steel 49 MnVS3 - facilities for heat treatment and the expenditure these involve are not required. As the risk of distortion and cracking is virtually eliminated, the right-hand side in the figure shows a solution, which is extremely advantageous from an technological, ecological and economic viewpoint.



Connecting rods (cars)

Figure 7: Connecting rods (passenger cars): substitution of materials taking into account technlologie, economy,and ecology

What has been described above and illustrated in the diagrams will become still more complicated in the future. The strategic triangle of materials engineering (Figure 5) which was characterized by the necessarily harmonic interaction of behavior during use, behavior during production and the basic price of the material, must be expanded - as illustrated in **Figure 8** - to cover an additional, fourth component, represented here as "environment". The most important finding is that in future it will be even more difficult to select the right material , namely one that meets all economical, technological and ecological demands!

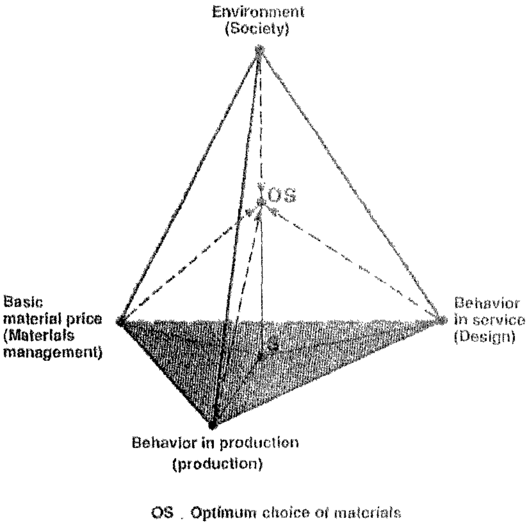


Figure 8: Strategies of industrial materials technology

In fundamental issues, this task will have to develop and become a team effort. A team effort in which the objective is an optimum solution reached in the only way it can be, by interdisciplinary cooperation on the part of specialists from various fields. At the same time this will relieve some of the burden of responsibility on development and design department, the necessity which was characterized by the fact that the level of responsibility for the product development department is extraordinarily high. This is especially true for the designer who specifies in his drawings what is to be used in a product from the beginning to the end.

This complexity, which affects the field of material selection with an enormous impact on the economical, ecological and technological result, must be mastered in the future. There are as yet no simple solutions which might be offered. But there is nothing else for it but to "think systemwise" in order to arrive at the right decisions after having made detailed analysis of the overall system. The whole material selection process will become considerably more complicated due to the fact that the development of the materials themselves is somehow in a crucial state. Although any revolutionary developments are not expected to be made that will have any influence on the materials used in the manufacturing of a motor car, there will possibly be developments of the evolutionary sort.

For a better understanding of this conclusion a short theoretical excursion has to be made. It is wellknown that all development processes of whatever sort - whether they be biological or technical or purely a matter of human behavior - can be represented by a growth curve whose law they follow. These growth curves start with a shallow slope that proceeds very slowly; this slope is followed by rapid growth which then in its upper region asymptotically approaches a limit. There are convincing examples that verify this process - these include, for example, a child's learning of his mother tongue, which follows this curve precisely - and this process approaches its limit at around 15 to 16 years of age. There is another excellent example describing the discovery of the chemical elements as it actually happened. A graph plotted against time similarly provides a growth curve with a very shallow initial slope. The search then became much more intense and vigorous and very many elements were discovered, which is to say the curve rose very steeply and - because the periodic system of the elements is of course, as everyone knows, limited - the curve naturally came to approach an upper limit, like water lilies on a pond that after all only has a limited surface area.

This relatively long preamble is necessary in order to explain the process as it occurred in materials development in the past. From this theory the course can be derived that development will take in the future.

At around the same time that motor car production began, but curiously a little before that, a manufacturing method was developed which made it possible to produce certain types of steel alloys: it was the Siemens-Martin process. This method was the start of a development which can also be illustrated in the form of an S-curve, as shown in **Figure 9**. You can see that from around 1950 onwards, the development began to approach an upper limit that looks very much like an asymptote. From the experience, of the car manufacturers it is known that since then there have been no absolutely new developments but a lot of modifications!

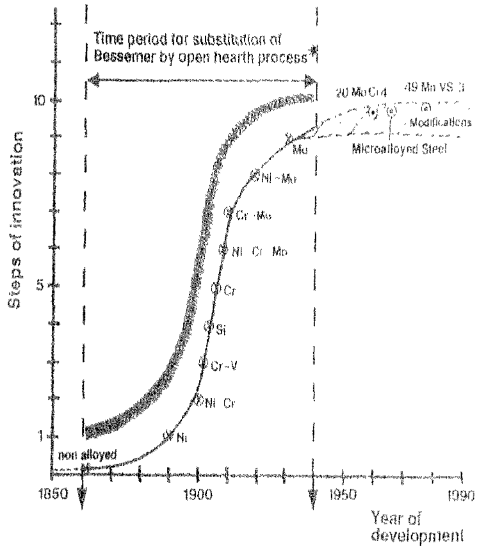


Figure 9: Steps in development of basic types of steel and use in automotive industry

In order to back up this statement, **Figure 10** shows a curve that is similar for the field of plastics with regard to innovation. Here too, a development started with the vulcanization of rubber - referring to as the first chemical process for producing plastics - which proceeded similarly in the form of a growth curve. In 1972, PES was presented, one of ICI's last basic developments, and one which virtually concluded the period of proper innovations. In this field, further modifications were developedly, copolymers, polyblends and similar evolutions ever since. Clearly, it seems that an upper limit will be approached in finding materials completely new!

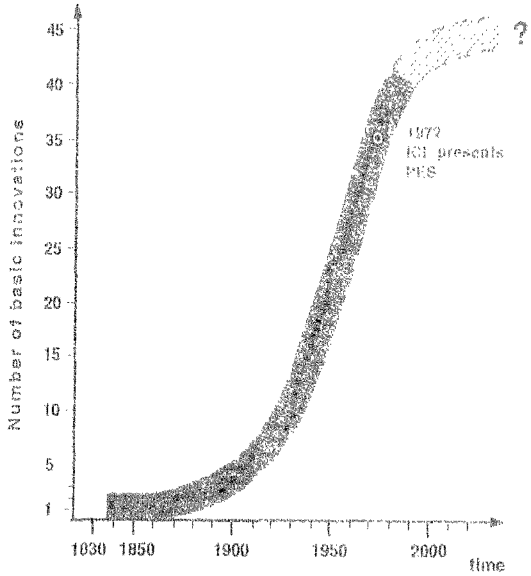


Figure 10: Steps in development of plastics

This upper limit to the capacity for genuine innovations is also mirrored in relationship with the use of plastics in vehicle manufacture, as illustrated in **Figure 11**. Starting with motor car production, a similar development occurs that quite clearly displays the character of an S-curve, even if certain question marks still hang over its upper reaches. The experts forecast that the limit probably will be reached somewhere between 12 and 15 %.

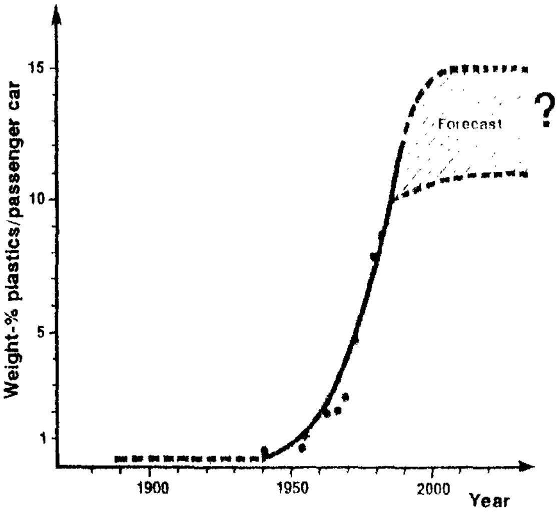


Figure 11: Use of plastics in the automotive industry

All this applies for normal technological development. Although development curves as illustrated above may be upset when fundamental influences take effect that have not direct bearing on technology or on the problems decribed, it is remarkable that neither the First nor the Second World War has led to any noticeable long-term deviations from the S-curve!! Nevertheless, "technological leaps" can be possible. Then they give rise to new growth curves.

The harmony of technology, economy and ecology which has already been a sort of leitmotif throughout the paper should be linked up with an illustration that appears to be useful for emphasizing the considerations expressed in many institutions today and for stimulating further one. Mercedes-Benz and Voest Alpine Stahl established a joint study group whose job it is both to study the disposal of disused vehicles and to develop feasible concepts aimed at resolving the still uncompletely solved problem of vehicle disposal. This is illustrated symbolically in the upper portion of Figure 12. The diagram describes the process as it proceeds from the disused vehicle, through its disassembly and finally to the point where the only remaining residue that is still left, the CO_2, is released into the atmosphere.

In this context a special mention to the CO_2 problem that exists today should be not given because it appears daily in the newspaper. The job of diminishing this problem using familiar techniques is possibly one for the future. One chance ist provided by the process illustrated in the lower half of Figure 12.

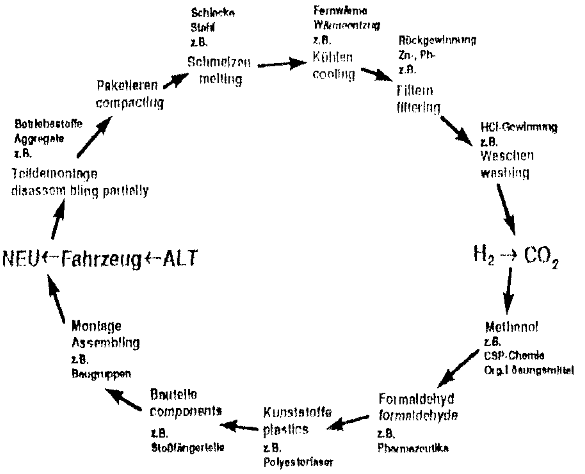


Figure 12: Total recycling of old cars

The combination of the first part, the recycling of metals, with the second part, the processing of CO_2 to produce raw material, i.e. the base material for manufacturing new plastics, will become the subject of the discussion in the future. It is clear that this can only be a cyclic process, which naturally requires additional use of energy since the laws of thermodynamics cannot be cancelled. But it has been proven repeatedly that this cyclic process is practicable from the point of view of materials and processes.

Today it is necessary to conduct analyses of this sort across the entire field of materials in the context of ecological considerations. There can be no doubt that economics and the influence that materials have on the productivity of a company are very closely related indeed and also have additional influence on the social parameters existing today. This has increasingly taken into account in the future.

Prof. Dr.-Ing. Claus Razim
Chief Environmental Officer of Mercedes-Benz AG
Senior Vice President for Technology and Environment, Mercedes-Benz AG, Stuttgart

Claus Razim was born in 1930. He studied Metallurgy at the Technical University of Berlin-Charlottenburg and at the Technical University of Aachen. He took other studies in special subjects of mechanical engineering, in physical chemistry as well as in anthroplogy and social ethics.
In 1967 he got his Ph.D. at the university of Stuttgart. In 1978 he was appointed to a professor at the Technical University of Berlin.

Prof. Razim started his career at the steel plants "Südwestfalen" in 1956. In 1958 he moved to the Central Department for Material Testing at Daimler-Benz AG.
In 1977 Razim became chief of the Central Material Department. In 1988 he was appointed to the senior director for the ressort Production Technics. One year later, he became director for the ressort Production-Technology and Environment at Mercedes-Benz AG. In 1990 he was appointed to the Chief Environmental Officer of the Mercedes-Benz AG by the managing board. In this function he reports directy to the manager of the managing board. He is a member of the committee "Environment" in the Daimler-Benz AG.

The task of Prof. Razim is to coordinate and to participate in the activities of the protection on environment and resources. Furthermore, he has to teach the knowledge on environmental protection to the co-workers and to promote the "Environmental Consciense" of each individual person.

In his function Prof. Razim has the chair of the committee "Technology and Environment" at Mercedes-Benz AG. The committee prepares recommendations with a special attention to the balance of Technology - Ecology - Economy to the managing board and supervises the realization of decisions.
For specific environmental problems - e.g. disused car recycling - the committee appoints project teams for the anaysis of problems and the proposals of solutions.

Prof. Razim is author of more than 50 publications and he received several honorships including the nomination to the Fellow of the ASM International (American Society of Metals) in 1988.

After his presidency of the committee "Materials" in the German Association for Engineers (VDI) he received the honorary medal in gold by the VDI. Since 1990 he is member of the advisory board in the material committee of the VDI. In 1987 and 1988 he was the chairman of the "International Federation of Heat Treatment" (IFHT).

Beside numerous memberships in scientific organizations and advisory boards Prof. Razim is the actual president of the environmental committee of the industrial association of Baden-Württemberg. In this function he is member of the advisory board "Environment" in Baden-Württemberg who advises the Ministry of Environment in environmental subjects.