Advanced Materials—a Critical View

By Claus Razim*

Competition in a free market makes ever more exacting demands on all kinds of manufacturers to offer products which are attractive in their performance and price. By using detailed knowledge and experience gained from theoretical and empirical studies, and by the increased application of computer technology in forms such as FEM (finite element methods), CAD (computer aided design), CAM (computer aided manufacturing), data banks, and computer networks, through to the currently much discussed "expert systems" and CIM (computer integrated manufacturing) systems, conventional methods and technologies can be pushed to the full limit of their potential. The urgency of taking advantage of opportunities such as these comes both from economic pressures and from policies on employment.

Further advances, which in many cases open up new markets, can result from increased use of microelectronics, and from putting into practice ideas for new products. Implementing such ideas in many cases gives rise to a desire, or an urgent need, for new materials, further developments of existing materials, or specially treated materials.

In view of this situation, one can understand why a number of countries have intensive research programs on materials science, and why this type of research is emphasized in the media. Although the media reports on modern materials technology are welcome, they are, unfortunately, too often associated with negative side effects. Thus one finds that the media are quite keen to cover aspects of materials technology, but the treatment is often superficial and distorted, owing to well-meaning attempts to present complex facts in a form which can be easily understood. The resulting neglect of scientific and factual consistency confuses the readers, listeners or viewers far more than if they were given a true factual account. In some circumstances this over-simplification can even lead people to draw false conclusions, which may have adverse effects on making special decisions related to work on materials.

For example, the need for progress in developing "revolutionary" materials—e.g., composites, ceramics, and superconductors—is very often emphasized in the media. Even in seriously regarded publications or broadcasts, euphoric reports announce "the end of the iron age", and promote "high tech" as the non-plus-ultra in materials technology. Such one-sided appraisal of unconventional materials developments carries the risk of neglecting the further development of cheap and already familiar conventional materials, which is absolutely essential on overall economic grounds.

The future for materials of very high performance is not restricted to "super-materials", which are certainly very important and which call for intensive efforts to make use of all their potential properties. Equally important is further work on conventional materials and their processing technology. This is made even more urgent by the fact that the relationships between materials properties and treatment processes, and between the properties of a material and the behavior of the components made from it, including their influence on the reliability of the overall assembly, are in many cases not sufficiently known, and have consequently not been formulated in engineering terms.

As an example, Figure 1 shows the remarkably large improvements in fatigue strength which can be obtained in steels through heat and surface treatments. The effects produced by such modifying treatments, and the details of the processes, depend on the type of alloy used, i.e., on its chemical composition, and from a metallurgical standpoint they arise from changes in the microstructure of the material. The ability to produce these changes is the basis for the extremely wide variations that are possible in manufacturing steels with macroscopic properties suited for different engineering uses.

Figure 2 shows the historical development of the different basic types of steels during the last 130 years. From the sigmoid shaped curve found here, which is typical in many different sorts of technological developments, it may be concluded that the development of fundamentally new types of steels is approaching an end! It can be seen that the basic types of steel now known were all developed within a period of about 60 years, and that from 1940 onwards, except for the microalloyed steels, no basically new types of iron alloy materials were "discovered". However, this by no means implies that development has come to a

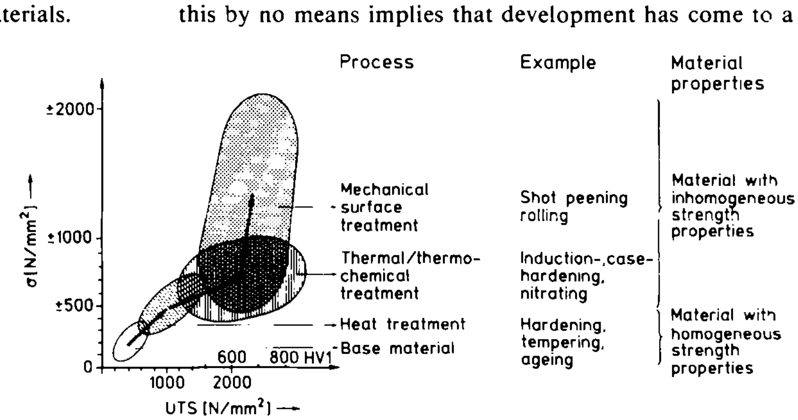

Fig. 1. Improvements in fatigue strength σ of steels by heat and surface treatments. UTS = ultimate tensile strength, HV1 = Vickers hardness.

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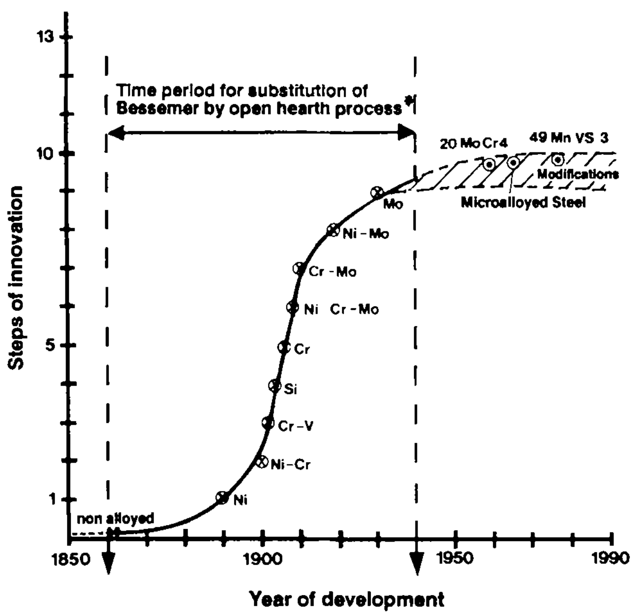

Fig. 2. Steps of development of basic types of steel (*G. H. Robinson*, General Motors Research Center 1980) and use in the automotive industry. *: *C. Marchetti, N. Nakicenovic*, Int. Inst. Appl. Systems Analysis, Laxenburg, Austria 1979.

stop; a wealth of modifications and variations of the known basic types have been developed, bringing about considerable improvements in the performance of these materials.

A remarkably similar development curve, though shifted in time by about 40 years, is found in the case of plastics. Here too, for about the past 15 years, in addition to an intensified use of blending technology, research has been dominated by modifications of already known basic types.

In the application of both the modified old and the new materials, an essential prerequisite is that suitable refined test methods must be developed and made available.

It is only through close interdisciplinary collaboration between chemists, physicists, materials scientists and engineers involved in design and production that new materials and the related treatment technologies for components with desired properties can be developed and successfully introduced into series production.

Irrespective of the choice of particular materials and appropriate treatment methods, the techno-economic aspects of industrial materials technology are of great importance. It is particularly essential to achieve a harmonic optimization of the key parameters of the cost of a material and its behavior during production and use.

Applying these criteria leads to the conclusion that steel and iron, due to their universal suitability, to the relative ease with which their mechanical, corrosion and tribological properties can be varied over a very wide range, and to their generally good processing behavior and ease of working, will continue in the foreseeable future to have great importance in the manufacture of vehicles, machines, and industrial plants. These favorable characteristics are further reinforced by relatively low material costs. An additional factor in favor of these materials, which should not be underestimated, is that of familiarity and long experience.

Depending on the type of application, on needs which are specific to particular business areas, and/or on cost considerations, it may be advantageous or essential to use other materials in place of steel. Those available include the broad palette of non-ferrous metals, ferrous and non-ferrous sintered materials, polymers and composite materials, ceramics, glass, and special materials such as memory metals, amorphous metals and superconductors. However, using materials such as these is not always free of problems, and would be unwise in some cases. For a material to possess just one outstanding property is not generally sufficient in engineering applications; the overall behavior with regard to a range of different properties is usually more important. Here again it may be possible to find solutions through interdisciplinary collaboration of the kind mentioned earlier.

In addition to considerations of function and cost, the choice of materials will become increasingly influenced by ecological factors, waste recycling and conservation of resources, not only for social reasons but equally importantly on economic grounds.

The complexity of the factors involved in finding the "optimal" materials to use in different applications, arising from the numerous aspects which must be considered, indicates a general increase in the importance of materials specialists.

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