Evolution of metallic materials beyond the year 2000

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Abstract
Over the next few decades an optimization of existing materials will drive the evolution of structural metals.
The focus will be on low cost manufacturing technologies for easy recycling. Integrated product development methodologies put in place in design platforms environment are the key for a succesfull exploitation of optimized materials.

Riassunto
Nei prossimi anni l'evoluzione di materiali metallici strutturali vedrà un'ottimizzazione dei materiali esistenti.
Importanti sviluppi sono prevedibili per le tecnologie di trasformazione a basso costo.
Le applicazioni dei materiali ottimizzati potranno beneficiare di una metodologia di progettazione integrata in grado di valutare i molteplici aspetti che rendano compatibili le alternative (costi, riciclaggio, valore aggiunto, qualità).

INTRODUCTION

It is certainly intriguing to try to detect the changes that may take place in the application of materials in a period such as the present with its exceptionally rich parade of social and political events. Stress needs to be laid, however, at the start of this survey on the fact that at least one generation must pass before a material makes an effective entry into both culture and production. The aluminium industry, for example, first appeared on the scene at the end of the 19th century, yet aluminium itself was not used on a wide scale until after the second world war. Most polymers were discovered between 1930 and 1950. Their industrial development, however, had to for wait the arrival of the 1960s. The first melt-zone purification of silicon was performed at the end of the 1940s, whereas the silicon industry did not spread until the 1960s.

Prediction of the possible technical evolution of materials over the next few decades, therefore, should not be so very difficult or uncertain. In the light of our current knowledge, we agree with the opinion expressed by many experts who belive that for all materials, especially for those of a "structural" nature, the next twenty years will not bring anything to compare with the upheaval caused by the diffusion of polymers and silicon chips. Instead, we shall see the optimisation of existing materials, the appearance of "new" materials being confined to very specific kinds to cater for highly specialised requirements.

PRODUCT DEVELOPMENT

The evolution of materials will undoubtedly be closely linked to the needs of the products required by the technical system of tomorrow.

This brief analysis is restricted to metallic materials. It is easy to forecast that steel, copper and aluminium will dominate and that far-reaching research is needed for their improvement: improvement of manufacturing processes, mechanical properties, shapeability and assembly technologies.

As to the subject of investments in research on materials, the amounts devoted to conventional materials, which still account for 95% of the market, and the so-called "new" materials are to our mind disproportionate when measured by the results obtained.

Where, indeed, are the results? Will this trend change because of the policies implemented during the last twenty years? In the more industrially advanced countries, this change has been in progress for some time and a reason of that is the rescaling of military needs for increasingly sophisticated materials whose use in civil applications has been very limited for both economic and other reasons.

Turning back to the question of the future development of structural materials, and confining ourselves to the presentation of a list, it is desirable to identify the current technical requirements, each of which would deserve fuller examination:

- more efficient manufacturing processes, resulting in lower product costs have to be developed;
- there will be a demand for products with improved mechanical properties;
- it will be possible to reduce the need for materials by 10-20% through further improvements in their resistance to corrosion;
- the energy content required for production, and the energy consumed during operation will have to be reduced;
- in other words, the global cost of a piece throughout its working life will have to be minimised;
- increasing preference will be accorded to materials with low specific gravity, especially in the transport, oil and packaging industries;
- reduction of the cost of semifinished products will be sought by encouraging innovative processing techniques: their cost will greatly exceed that of the material itself;
- easy-to-assemble materials will form the subject of incentives;
- regulations governing emissions into the atmosphere will have to be strictly complied with;
- the question of recyclability will have be solved completely: increasing qualitative and quantitative use will be made of recycled materials that do not produce pollutants, and manufacturers will be responsible for the retrieval and final disposal of all their products.

DEVELOPMENT OF THE RANGE OF CHOICE

In identifying the materials that may still be successful in the technical system of tomorrow, it must be clear that for all materials a "technical trust" needs to be offset by a "market guide" and screened by a "social guide". Even the best material is only useful in a particular application if it provides the answer to precise requirements or involves a real innovation that can be economically accepted by the society in which we live and work.

Special requirements often lead to the purpose-oriented designing of a material and its corresponding fabrication process, which is of essential importance in obtaining the specifications required.

Yet every development of "innovative" materials causes stimuli that lead in their turn to innovations and further improvements of traditional materials in the competing sections they threaten. Ferrous and non-ferrous materials remain the best known and the most employed they still have a fundamental role and a leading position in engineering applications.

Over the next few years the metallurgy will have to keep this position also one of the prerequisites for the survival of this industrial sector in all the more developed countries. One of the strong points in this challenge is quality and its economic and commercial value.

Improvement of quality and harsher competition are certainly the focal points upon which attention has been concentrated with regard to the future development of metals. Metallurgical research is oriented towards this aim, it is still rather lively and is moving in the directions listed above for the development of each product in all its families and classes.

To provide a clearer picture of our opinion about tomorrow's developments, we have decided taking by way of example a sufficiently wide sector, namely that of metallic materials for mechanical applications. These are employed in the automotive, rail and transport industries, in the generation of energy, in the extraction of oil and natural gas, in manufacturing, etc.

And, among these, significant examples have been drawn from the automotive industry.

Very often the requests of the market constitute a veritable metallurgical challenge to the producer, who needs, for example, to increase strength levels while maintaining or, if possible, increasing toughness, machinability, shapeability and weldability, and all this will has to be achieved at the lowest possible cost.

The answer comes from the wedding of various components: modern metallurgical processes, application of the latest advances in physical metallurgy, design optimisation, development of component fabrication processes, application of advanced investigation techniques, such as those proposed by fracture mechanics. The success of this extension of applications requires coordinated cooperation involving the designer, the process metallurgist, the component manufacturer, and the end user.

It must be acknowledged that those engaged in the study of materials designers and technologists are being increasingly called upon to operate in a coordinated manner to solve problems of an interdisciplinary nature. But it is equally true that difficulties in the two-way exchanging of knowledge and skills still persist. These difficulties must be removed to allow the establishment of a correct form of collaboration aimed at the development of new solutions.

With this in mind, therefore, we hope that what follows will clearly bring out the importance of overcoming the last integration difficulties that still exist between those engaged in the study of materials, designers and technologists.

By identifying industry as the place where scientific knowledge is converted into technical innovation and hence in products and tools directed towards economic and civil growth, we can underline the way in which, in our view, the question of the evolution of the application of metallic materials must be tackled in the immediate future. We will use some example to reach this aim.

RECENT FACTORS INFLUENCING EVOLUTION

Evolution of the application of materials for the fabrication of components in the industry is being increasingly influenced and piloted by factors like:

- economy: global competitiveness calls for the production of components with low-cost technologies, restricted capital expenditures and inexpensive processes;
- the market: customers are becoming ever more exacting and the competition is out to satisfy their expectations, which means that the performance of components must be something more than just sufficient;
- environment: regulations governing emissions into the atmosphere and reduction of the greenhouse effect are becoming increasingly restrictive, and recycling and disposal of the materials employed must not be the source of pollution;
- saving of energy and natural resources: it is necessary to move towards lower consumption levels and the more rational employment of raw materials, and hence the greater use of what is recycled.

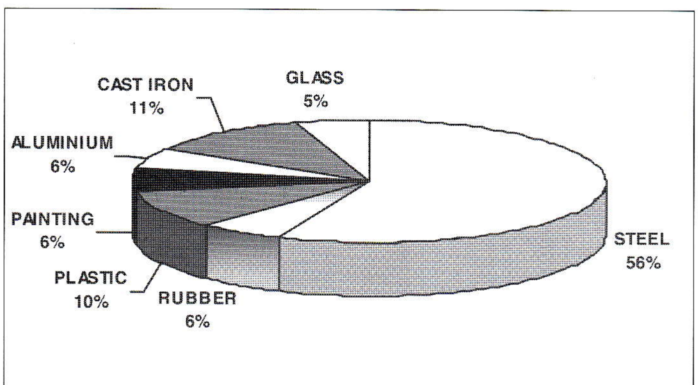


Fig. 1: Per cent distribution of the use of materials in vehicle construction

For the automotive industry, two other factors have to be added to the namely above mentioned ones:

1. the need to make vehicles lighter while maintaining or improving their performance and safety through the use of lighter materials;
2. cost competitiveness with higher quality.

The current breakdown of the main materials used in the manufacture of an average-class vehicle is illustrated in the pie chart in fig.1.

As to the question of weight reduction, it can be seen that two main reasons are encouraging the manufacture of lighter means of transport: lower consumption for the conservation of natural resources, and reduction of emissions into the atmosphere to limit the greenhouse effect and pollution.

Regulation of these two factors is becoming and will go on becoming increasingly restrictive. Fig. 2 shows the evolution of the emission standards in grammes per kilometre laid down

Date	Application	CO	HC& NOx	HC	NOx	Uncombusted
1/1/1993	all engines	2.72	0.97	-	-	0.140
1/1/1996	spark ignition engines direct-injection diesel indirect-injection diesel	2.20 1.00 1.00	0.50 0.70 0.90	- - -	- - -	0.1403 0.080 0.100
In the ratification process	all i.c. engines	0.64	-	0.56	0.50	0.050
To be prepared	all i.c. engines	0.50	-	0.30	0.25	0.025

Fig. 2: Evolution of atmosphere emission standards in g/km (Source: E.U.)

for European vehicles already in force since 1993 and envisaged for 2005.

All automakers, therefore, are heavily engaged in the search for applications of materials that will achieve appreciable savings in vehicle weight, while at the same time they are having to offset the increasing weights brought about to secure greater safety and comfort, such as power steering, air conditioners, hydraulic drive, impact beams, additional electric motors, etc.

Figure 3 shows what Ford has planned for the reduction of the weight of its vehicles in the year 2005.

MODEL	Taurus GL 1997	Ford P2000-2005	D Weight %
Body	711	396	-44
Chassis	368	217	-40
Powertrain	360	257	-28
Fuel	(63)	(35)	-44
TOTAL	1.439	870	-40

Fig. 3: Weight reductions (in kg) planned by Ford for 2005 MODEL

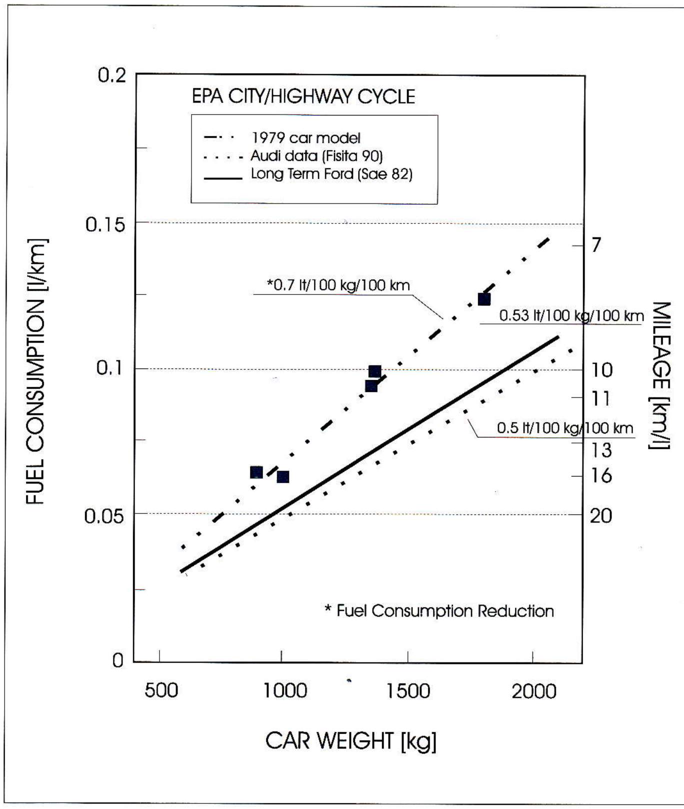


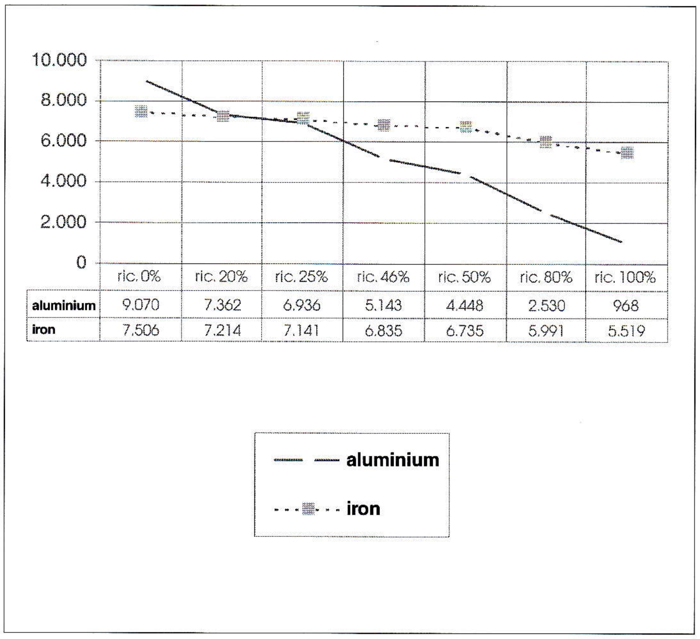
Fig. 4: Fuel consumption in function of vehicle weight over a combined cycle in accordance with the EPA standards.

An idea of the correlation between total weight, weight reduction and reduction of fuel consumption can be gained from fig.4, which shows the fuel savings obtained per 100 kg over a 100-km journey in function of the total weight and the year of manufacture of the vehicle.

Research on materials that can be employed to reduce component weights is thus one of the leading objectives and challenges. The target to be reached by the years 2005-2010 is 3 litres per 100 km for an average-sized vehicle weighing about 800 kg. Yet mere lightening to save energy during use is not enough. There is no point in using materials with an excellent weight/performance ratio if they are very expensive, if their extraction and fabrication are very costly, or if their disposal and recycling are very difficult. The choice of a material, in other words, must take account of its overall energy consumption and emissions into the atmosphere during its working life and its disposal or recycling. This aspect is illustrated in the following graphs.

In fig. 5, a comparison is made between the total energy (in MJ) consumed during the life of a 30 kg aluminium and a 70 kg iron engine block casting in function of different recycling percentages.

It is clear, therefore, that selection of a material is partly governed by its potential recyclability, which must thus be increasingly incentivated by government. Metallurgical re-



	ric. 0%	ric. 20%	ric. 25%	ric. 46%	ric. 50%	ric. 80%	ric. 100%
aluminium	9.070	7.362	6.936	5.143	4.448	2.530	968
iron	7.506	7.214	7.141	6.835	6.735	5.991	5.519

Fig. 5: Energy consumption (MJ) of an aluminium and an iron casting in function of recycling percentage

search, too, must set out to devise alloys that can also be generated from recycled materials and are suitable for a given component.
The same is true with regard to emissions as can be seen in figs. 6 & 7, where a comparison is made between the CO2 emissions of the two types of casting in function of recycling percentage.
These data are essential aids in choosing a material, adapting abatement and entrapment plants through the elaboration of appropriate specifications for their suppliers, and keeping within the increasingly strict standards throughout the world.
It is clear from these examples that the use of light metals (mainly aluminium and magnesium alloys), optimisation of the employment of ferrous materials and their large-scale recycling are going to be virtually a must in the short term.

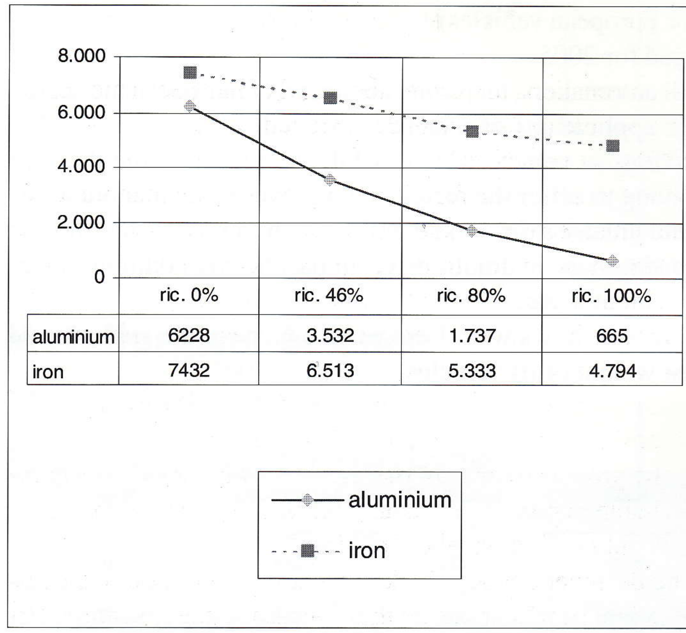


Fig.6: CO2 emissions (in m³) in function of recycling percentage

	30 kg aluminium alloy - % recycled				70 kg iron- % recycled			
%	0%	46%	80%	100%	0%	46%	80%	100%
CO	16,110,571	9,112,108	4,270,738	1,378,154	186,902	1,72,472	152,658	143,625
SOx	6,288,158	3,567,494	1,710,723	601,354	7,297,983	6,363,434	5,157,038	4,607,001
NOx	93,084	93,084	93,084	93,084	2,018,328	1,917,322	1,763,700	1,693,659
HC	2,693,212	1,527,283	823,672	403,284	1,486,716	1,505,027	1,500,836	1,498,925

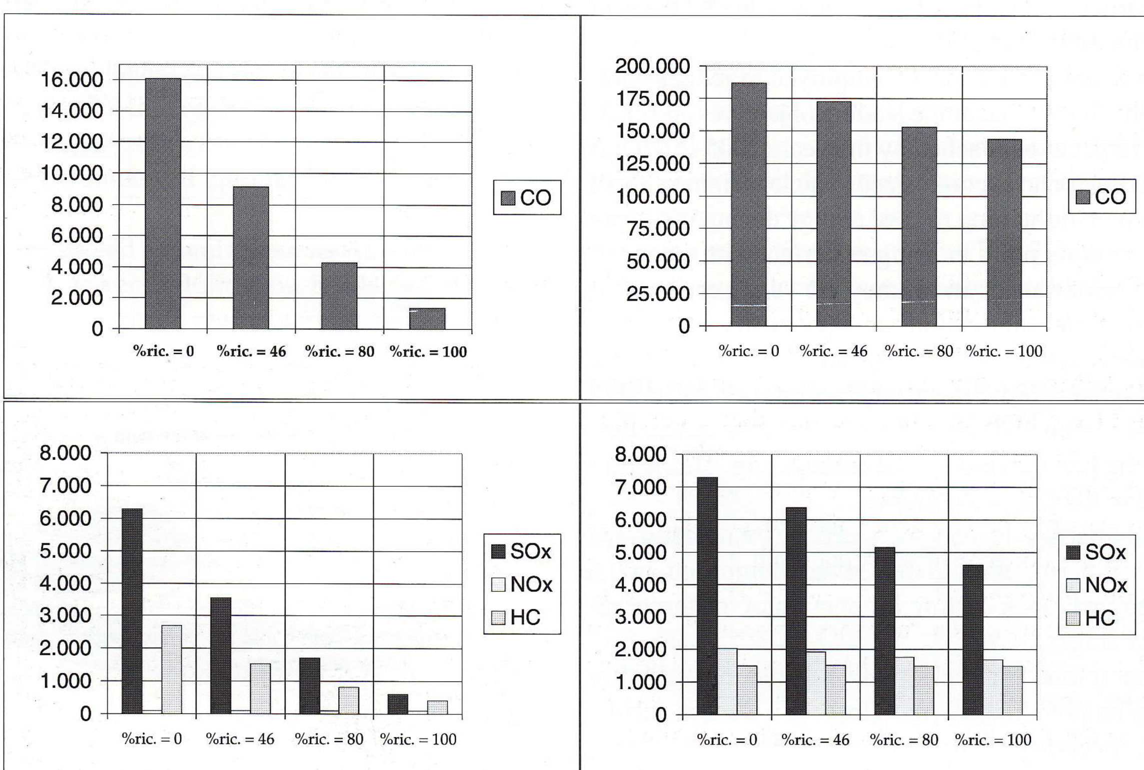


Fig.7: Total emissions (in mg) in function of recycling percentage

EXAMPLES OF APPLICATION

Three questions are suggested by what has been said so far:
How should a component be designed?
With what materials?
What technologies should be employed in its manufacture?
One must start from some considerations that may seem to be simply taken for granted, yet they provide the sole assurance that a product will be a success on the market, profitable for its manufacturer and in keeping with the external constraints, in fact it must:

- perform a function required by the specifications;
- possess a value recognised by the market
- be produced through the use of technologies that are reliable in repetitive manufacturing and thus ensure a constant level of excellent quality.

The designer usually thinks of a component in terms of its functional application and thus focuses on the first point. His cultural background and professional involvement do not allow him to be very sensitive over such matters as costs, constant updating of materials and manufacturing processes. This situation is normally logical if we consider how many alternatives there are in the way of available materials, technologies and production systems that are in the process of development and usually involve a variety of professional skills; the price is always estabilished by the market, but costs should be "designed" at the same time as the component to be certain from the beginning that they will make the price attractive. These costs are always determined by the materials employed and the technology adopted, and hence by the expended capital. A design department, therefore, cannot of its own accord ensure that even solutions which are optimal technically and with respect to their application will be duly appreciated by the market. We have already underscored the need for closer integration between the key competencies in the integrated process: design in the true sense, materials, technologies. What has just been said corroborates this need and industry must adapt, account being also taken of the very satisfactory experiences already recorded in other industrial countries (Japan, the U.S., Germany, etc.) It has been demonstrated that this is only the first step towards fuller optimisation of the system, since the fact that a complex multiplicity of skills are involved means that others (Purchases, Marketing, Quality, Staff, etc.) must be integrated. We are thus witnessing the emergence of extended "platforms" that start from the concept of a product and embrace in a working group all the in-house and external skills so as to generate what is known as a "network company". This in turn raises the problem of how to handle and regulate this system in order to ensure that all the contributions are synergic and focused on the objective to be reached. The solution cannot be generically called for from people's willingness to cooperate and integrate. There must be the support of strict, objective methodological guidance capable of advancing the definition of the solutions according to an optimal method. One must put together not only the functional and technological aspects of a component, but also all the other collateral, though not secondary, aspects to define what for a given component will be:

- the value recognised by the market;
- the best way to design the component;
- the best materials to use;
- the best way to make and to experiment the prototypes;
- the best technologies and processes suitable for its fabrication;
- the maximum speed of introduction on the market.

The best choice can only be made through correlated and weighted evaluation of all the possible solutions, both those that already exist and those foreseeable from a consideration of all the parameters that evolution of materials and technologies may show in the future. If this latter aspect of the question is overlooked, in fact, a solution may well prove appropriate for the current scenario, but with the risk of being outdated by other more innovative solutions when it is eventually placed on the market.
There is thus a need for constant attention and broad-spectrum updating on the evolution of materials and processes to be supported by a strong engagement in applied research and continuous comparison with the best in each and every sector.
The way this method is applied is illustrated below with reference to the definition of a cross-member for a suspension. It follows logical steps that proceed from the identification of what the market requires, i.e. a product whose soundness and value it is prepared to recognise.
This identification is the starting-point for the conception of the comprehensive functional system (the suspensions). One then descends through measured and correlated eveluations into ever greater detail until one obtains a comparative picture of all the possible alternatives and an indication of the optimum materials and processes for the individual structural component (the cross-member - Fig. 8).

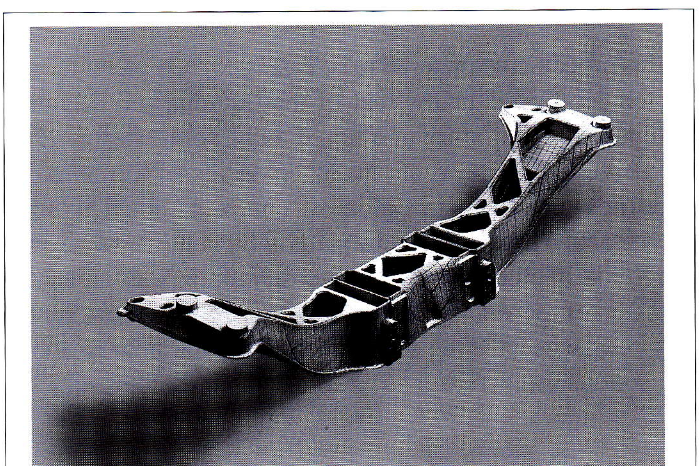


Fig. 8: Car suspension cross-member

From the application example particular reference must be made to the final evaluation to secure a better understanding of what has been said about the optimum definition (in the sense that it takes all the variables, including the market area, into account) of the material and the technology indicated as most likely to be successful.
Evaluation, in fact, of the correlation between the parameters and physical characteristics of the materials on the Y axis and the characteristics resulting from the various applications of the technologies applicable to the materials themselves on the X axis reveals the optimum industrial solution (for emerging markets in this case).
The evaluation coefficients employed must obviously be drawn from updated data banks containing experimentally objectivated parameter values for the materials, and realistically reliable ones for the processes.
This example can also be used to illustrate some developments of the processes which place in competition various materials that, according to the technology applied, may result in the prevalence of the use of one material rather than another.
The indicators thus point to a solution in hydroformed steel, whereby a conventional carbon steel combined with an innovative technology can compete on emerging markets, whereas aluminium is preferable for other market areas and segments.

5.1 Suspension struts and wishbones

In this case we show how the conventional use of cast iron may tend to be replaced by aluminium alloys. By contrast with the cross-member, which is hollow, these components can be produced by means of innovative technologies to confer on the alloy itself characteristics that meet the specifications and result in a weight saving of the order of 30% (Fig. 9).
Two new technologies are involved:
- semisolid forming (thixocasting);
- squeeze casting.

Until very recently forging was the only way in which aluminium alloys could be used for these products. However this method, certainly provided an optimum answer to the specifications, but it was very costly and could only be applied in the case of high-performance vehicles.

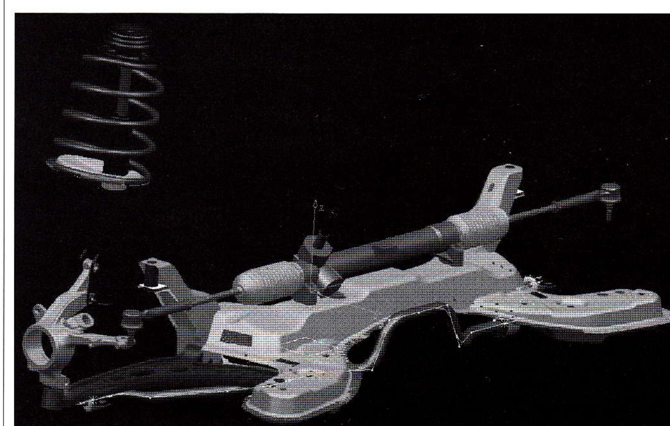


Fig. 9: Front wheel struts

SEMISOLID FORMING (THIXOCASTING)

Process description

In this process, the material to be cast is not completely fluid. Its temperature is below that of the liquidus and it is thus composed of a mixture of a liquid and a solid phase.
Intensive stirring prevents the otherwise usual formation of dendrites and results in a globular conformation. This state is typical of a thixotropic flow pattern. By contrast with Newton fluids, in other words, the viscosity diminishes greatly in function of increasing tangential stress. The process generally consists of heating segments of a flowcast bar to above the solidus temperature so as to establish the desired ratio (about 60%) between the solid and the liquid phase. Five advantages are obtained by pressure diecasting a material in this state:
- no porosity
- less shrinkage
- less energy consumption for heating
- better mechanical properties (especially elongation)
- optimum dimensional precision and machining allowances

SQUEEZE CASTING

Process description

This process is carried out by measured pouring of an aluminium alloy into a open forging die and applying an appropriate pressure before the mass solidifies.
The pouring temperature depends on the type of alloy but it is always above the liquidus.

The matrix dies are held between 190 and 315°C and the punches are not heated.
The pressure depends on the geometry of the piece and is about 70 MPa. It is applied for from 30 to 120 seconds for a piece weighing about 9 kg, depending once again on its geometry. The dies are spray-lubricated with an aqueous solution of colloidal graphite.

An idea of the final characteristics of the material can be gained from fig. 10, which compares the application of thixocasting and squeeze casting in the manufacture of various components.

Gas inclusions are drastically reduced in each case allowing the material to be heat treated. This is of great importance since they have a direct influence on the mechanical characteristics of a material. Gas content figures for castings produced using various technologies are compared in fig. 11.

	component	alloy	R_m (mPa)	$R_{p0.2}$ (mPa)	A (%)
	wheel bearing	AlSi7Cu3	225	178	3.0
Thixocasting	brake cylinder	AlSi7Mg	309	245	11
	railing nodes	AlSi7Mg	320	240	12
	wheel bearing	AlSi7Mg	326	288	4.9
	steering box	AlSi9Cu3	317	258	2.7
Squeeze casting	wheel hub	7075	577	508	5.0
	wheel	2014 T4)	467	436	10
	wheel framework	AlSi7Mg	297	235	7.1
	bicycle frame	AlSi7Mg	352	294	7.5

Fig. 10: Comparison between the two technologies

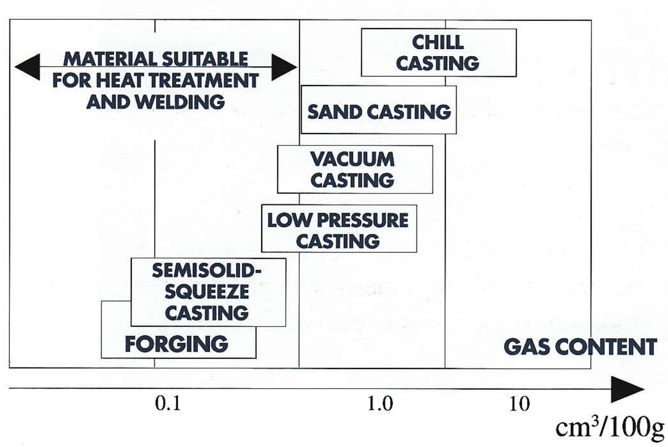


Fig. 11: Gas contents in castings produced using various technologies

5.2 Constant-velocity joints

The functional diagram of a constant-velocity joint is set out in fig. 12.
Steel is irreplaceable for these parts. Even so, examination and listing of all the various possibilities provided by the new technologies, design and process simulation methods have resulted in races finished with fewer machining operations, better performance and lower weight.
The dimensions of this part had to be determined so as to take account of the fact that shearing of the fibres of the forged piece in the area of the races diminished their mechanical characteristics. In addition, the operation itself was expensive due to wastage of material and high tool and investment costs, and also critical owing to the risk of division errors in the race gaps.

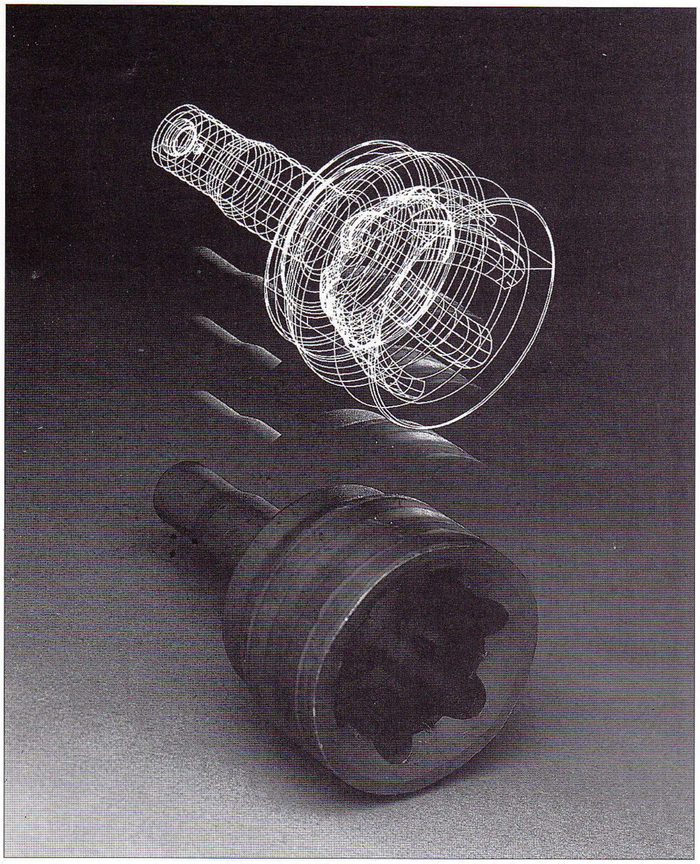


Fig. 12: Constant-velocity joint for front-wheel drive

The new warm forming and cold finishing technologies (fig. 13) and titanium nitride cladding of the tools have resulted in the perfection of a technique that enables the specifications required to be met with high-carbon (C 53) steels.
The elaboration of this innovative and highly competitive process was once again the outcome of cooperation between experts in materials from steelworks, experts in forming technology (including machine manufacturers), experts in tooling and cladding, and designers. The steel, too, was improved through the inclusions of a controlled resulphurising stage during its manufacture to achieve a predetermined inclusional state ensuring better machinability.
The initial billet must be cut with a high-precision shearing machine, since all the forming operations are conducted in a closed die and very high constancy and volume precision are essential.
The billet is heated to about 200°C in the first part of the induction furnace and automatically prelubricated by immersion in a tank containing an aqueous graphite solution before returning to the reels for the final heating to 830-850°C. The hand of the transfer press then passes it through the five progressive die stations to produce the body of the joints with its races roughed out at tolerance levels sufficient for the subsequent cold finishing operations.
The preformed piece is now annealed and phosphated prior to the cold calibration and closing of its races.
The line is fully automated and its reliability ensures the maintenance of the tight tolerances (> 0.3 mm) required.

5.3 Conneting rods

Conneting rods are conventionally made of cast iron and hardening steels. Alternative technologies have been devised to meet the market's current requirements.
Nodular iron will continue to be used for straightforward applications and low-capacity engines, since the cost of the finished product, obviously including its machining operations, will still be the most competitive.
When higher stresses are involved, steel will remain the best option. New techniques and materials, however, have been evolved to make it more competitive.
Hardening steel, in fact, has been replaced by particularly

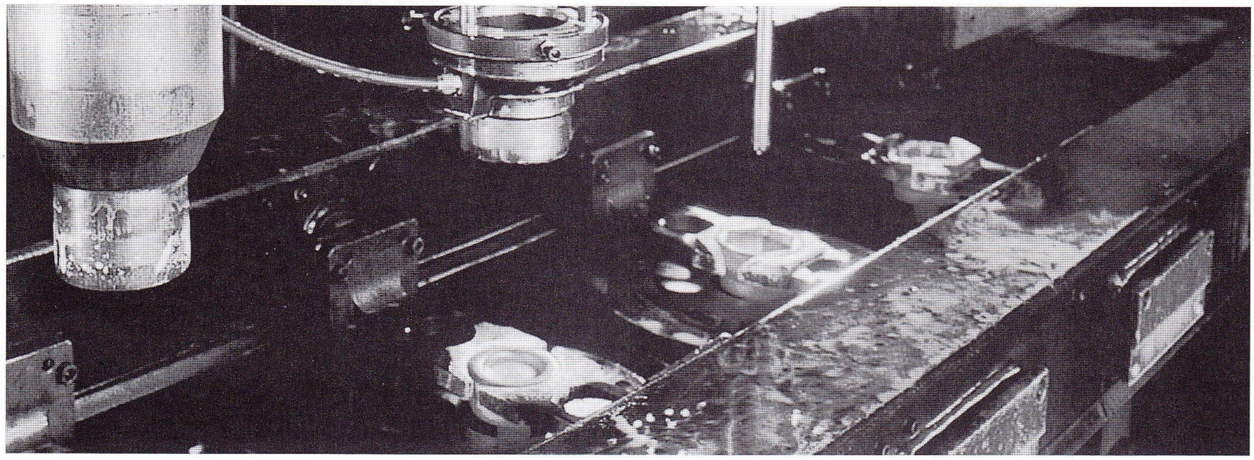


Fig. 13: Warm forming operations for manufacturing near net shape cv-joints

pure carbon steels (C70) with very similar mechanical characteristics obtained by controlled cooling alone. Another important feature of these steels is that they can be used to forge conneting rods complete with their caps. These are then detached by fracture splitting and their costly mechanical separation and chip removal are eliminated. This process is illustrated in fig. 14.
Caps separated in this way and then assembled remain more firmly and precisely anchored to the connecting rod shaft. Their bolts have thus been simplified and the entire assembly has become less costly.
Another alternative has been provided by the use of powder metallurgy to produce sinterforged conneting rods. In this interesting process, conventional compacting and sintering are employed to fabricate a preliminary shape that is then heated to 1200°C and forged in a closed die.

Its final density is 98% of that of steel. This technology is very sound and has already been adopted by Ford for engines up to 2 litres. Its very high dimensional precision does away with the need to classify conneting rods by weight before assembly (weight tolerance ± 3 g) and fracture splitting of the cap is also possible.
The major drawback, however, is that metal powders are still expensive.
Sinterforging and the advantages it offers by comparison with a conventionally forged con rod are described below.
The sinterforging process does away with the need to classify conneting rods by weight and four machine tool operations:
- Spot facing
- Roughing-out of the small end and big end eyes

New-generation steel con rods
Fracture splitting of the cap

Process
The conneting rod is produced by hot forging, warm calibration and controlled cooling. The splitting operation is rendered highly repeatable by using a laser beam at the start to etch the fracture area.

Results
Elimination of costly mechanical separation of the cap. Precise recoupling allows the use of very simple bolts.
Reduced investments and plant space requirements.

Reduction of operating costs
- Energy saving (up to 40%)
- Lower plant costs (up to 35%)

Product/process characteristics
- High fatigue strength
- Less weight
- Shot-blasting
- Warm calibration
- Controlled cooling
- Tight weight tolerances

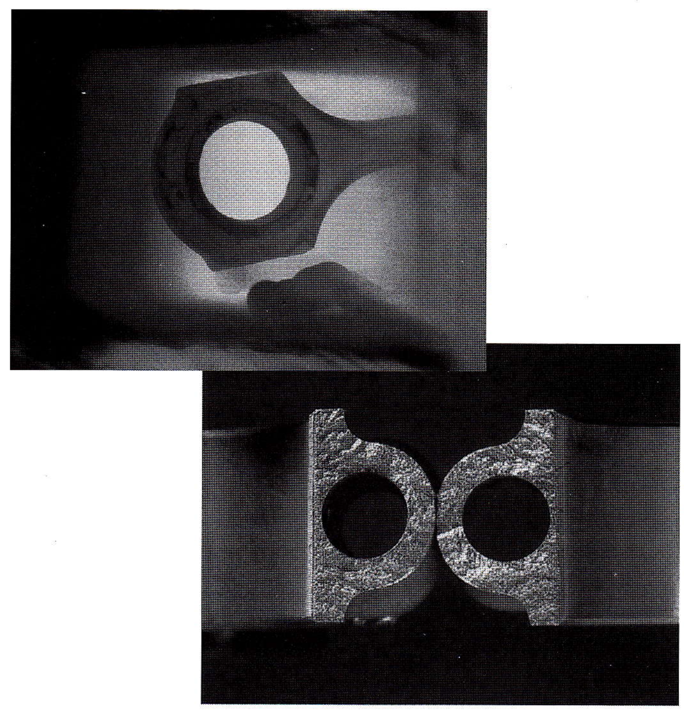


Fig. 14: Conneting rods with fracture-split cap

- Facing of the cap bolt seating
- Machining of the head of the cap

The process consists of six stages:
1. Cold compaction of the powder with a hydraulic press
2. 100% workpiece weight check
3. Sintering at 1200°C in a controlled atmosphere furnace
4. Transfer to the forging press
5. Forging with a 600-tonne press and water-graphite lubrication
6. Controlled cooling

5.4 Exhaust manifolds

Increasing use is being made of an up-and-coming technology known as hydroforming in the production of exhaust manifolds (fig.15).
Cast iron has long been regarded as best for the manufacture of exhaust manifolds on account of its competitive cost and its good resistance to high gas temperatures.
Optimisation of its competitiveness, however, requires the solution of two problems associated with its performance and its weight.

The first stems from the fact that the inner surfaces of the ducts in a casting are not smooth. Their roughness is dependent on the superficial quality of the cores and cannot be reduced because of the limits of the process. The weight factor is determined by the thickness of the walls. This has been minimised as far as possible (2.8 mm in the best cases). Further reductions, however, require the employment of very costly process expedients.
Research has thus been directed to hydroforming. This gives very thin sections even with stainless steels, which make excellent exhaust manifolds, able to answer to the future engine higher demanding performances (higher gas temperature).
Hydroforming offers up to 60% deformation of cross sections with dimension tolerances of less than 5%. A further advantage is that the thickness of the material is not reduced at bends as it is during conventional drawing.
The process is described in fig. 16.
This technology makes use of stainless steel tubing cut to convenient lengths. The shear section is deburred and the lubricated tube is placed in a hydraulically closed die. Two axial punches seal the ends of the tube and are drilled at the central axis. An oily solution is injected at high pressure through this hole. The punches are operated axially and their thrust, combined with the pressure of the solution, deforms the tube to fit the surfaces of the closed die. Handling of this process is rather sophisticated since a constant check must be made of the perfect tightness, while the internal pressure and the forward travel of the axial punches must be piloted in function of the deformation.
Stages of the process are:
tubing, cut length, deburring of the shear zone, phosphating of the tube, closure of the die (up to 1800 kN), injection of fluid under pressure and axial thrust (up to 300 kN per punch).
Envisaged advantages are:
- Simpler dies (lower costs)
- Lessmachining operations
- Better deformation distribution
- Shorter lead time
- Better component quality

The fabrication cycle time is 20-30 seconds. The process is therefore suitable for niche manufacturing or short runs. It also allows a variety of materials and thicknesses to be pressed with the same die.

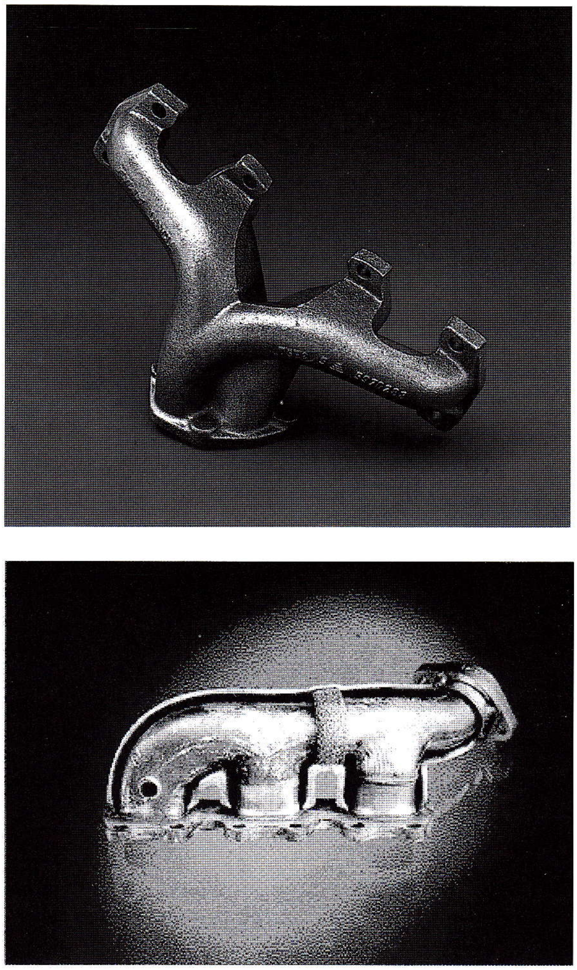


Fig. 15: Comparison of a cast-iron and a hydroformed exhaust manifold

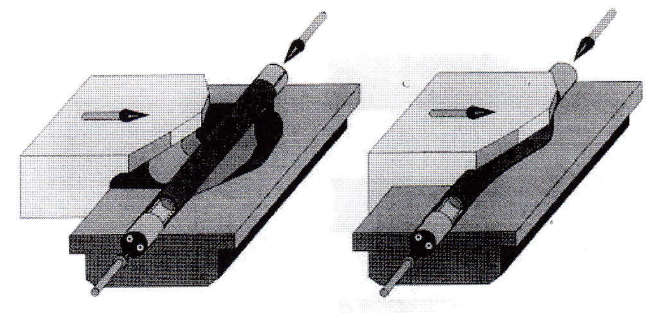


Fig. 16: Typical hydroforming process steps

5.5 Magnesium components

Magnesium alloys were being applied in the 1970s. They were subequently abandoned owing to the high cost of the raw material and the process, and corrosion problems. The cost of magnesium was high and unstable owing to its limited production worldwide. The need to reduce vehicle weights has driven all automakers to seriously reconsider this material with the result that the production of magnesium and its alloys is being adjusted to the new demand.

Magnesium's attractive mechanical and pouring properties result in components that are 40% and 20% lighter than those in steel and aluminium respectively. Moreover its excellent flowing through the cavities of a die facilitates the construction of complex shapes and sometimes enables separately made parts to be combined in a single piece.
The main physical characteristics of some magnesium alloys are shown in fig. 17. Three components already being made with these alloys are illustrated in fig. 18 the production process can be seen in fig. 19 (die operating).
Use is made of pressure diecasting machines equipped with sensors that check all the process parameters, mainly the forward travel speed of the injection plunger. The casting system and the system for metering the liquid to be injected in the die are fundamental. All these operations are conducted in inert gases to prevent the molten metal from coming into contact with the oxygen in the air.

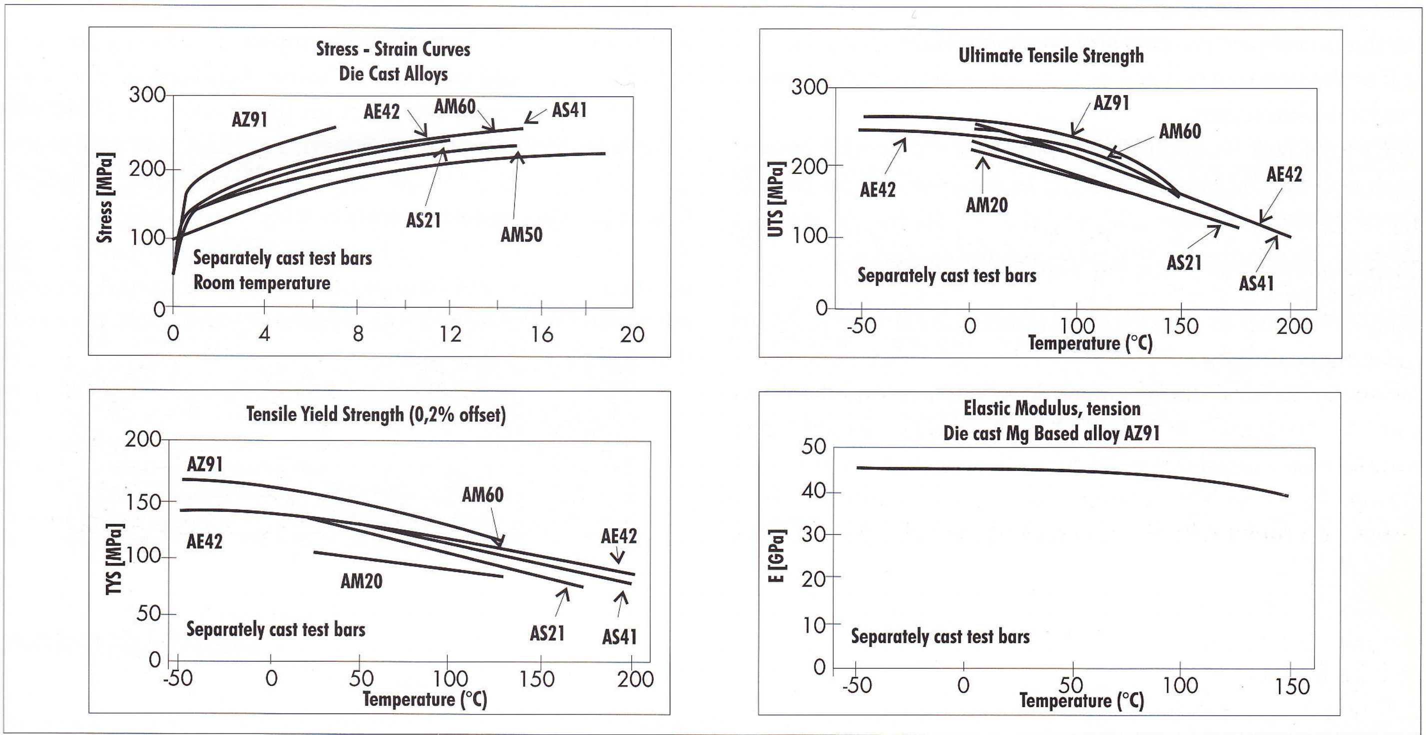


Fig. 17: Main physical characteristics of some magnesium alloys

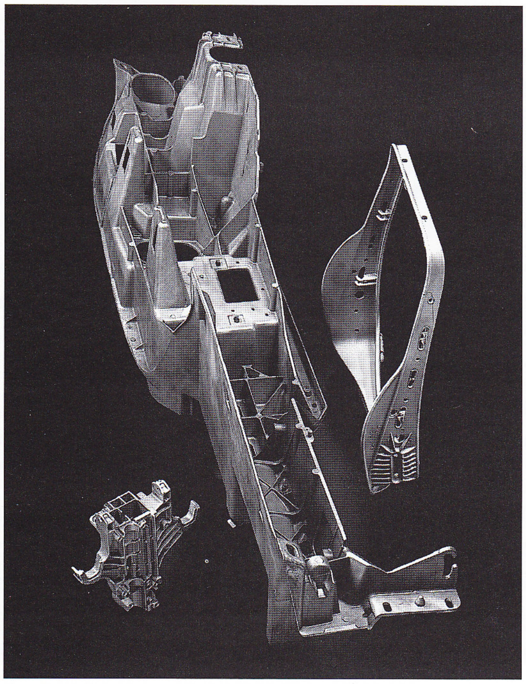


Fig. 18: Some magnesium alloy parts

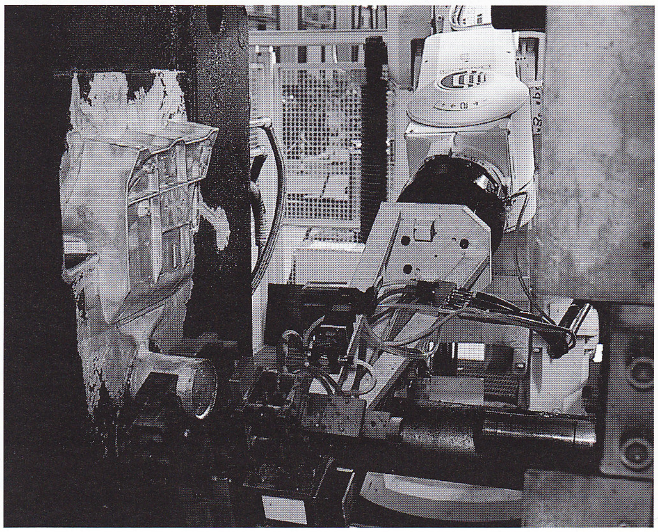


Fig. 19: Magnesium alloy casting technology

CONCLUSIONS

Most metallic materials used in engineering over the next twenty-five years will be those now regarded as traditional. Their structural and functional properties, of course, will need to be improved, along with optimisation of their production costs, better transformation processes, incentivation of recyclability, etc.

The time is certainly delicate both for manufacturing industries and the users of all materials. The need to make quality products competitive cost and product reliability demands a full understanding of various types of material and transformation technologies.

The use of new technologies in products is essential, even if such use may be either direct, as in the case of "innovated" types of steel, ferrous and non-ferrous alloys, or indirect through improvements in design, reliability, services or marketing.

Integrated product development methodologies are required to be succesfull.

We underline importance of acting jointly to attain the interaction of skills between those who study materials, designers and technologists so as to encourage the establishment of a flexible, more open innovative system capable of identifying practical solutions applicable to the needs that appear on each occasion.

Our prime intention, however, was to stress that the factors influencing the choice of the most suitable material have increased. The constraints that determine such a choice are forcing the designer to be mainly concentrated on the functional aspect of the component.

In conclusion, it's important to emphasise what is happening in the iron and steel sector: more than 50% of the products now being sold were not on the market, or could not have been produced ten years ago. This fact may well come as a surprise to most of our readers. It is certainly an indication of the very great commitment for users.

This commitment, which has been and is continuing to be pursued by the steel industry through product and process innovation, is a sign of the dynamism and great potential that still exist in this sector.

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