EUROPEAN COLLABORATION IN THE FIELD OF HIGH TEMPERATURE MATERIALS

by

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THE COST FRAMEWORK

COST i.e. European cooperation in the field of Scientific and Technical Research, forms a framework and forum for international research cooperation, and includes all the European OECD Member States.

COST is closely bound up with the creation of important sections of European Community research policy and constitutes a framework for cooperation between the European Community and European non-Member States in the field of research and development. Joint research planning is carried through a "concerted action", which means that financing is provided by the individual States.

COST PROJECT 50

The agreement for a concerted action project on gas turbine materials was signed on 23 November 1971 at the Ministerial Conference on European Cooperation in Scientific Research (COST). The need for a collaborative programme in this area of technology arose from the recognition that Europe was lagging behind the United States and that the future competitive position of the relevant industries depended on a more efficient research effort. The COST Project provided an opportunity to benefit from the synergy that was expected to result from the integration of relatively small research countries. Cooperation was helped by the fact that the major turbine builders and alloys producers believed that competition in Europe was chiefly from US-based companies and not from one another.

The countries signing the agreement were the Federal Republic of Germany, France, Italy, Luxemburg, the Netherlands, Austria, Switzerland, Sweden, the United Kingdom and Belgium.

The technical terms of reference agreed by the participating countries specifically restricted the Project to "hot-end" materials i.e., Ni, Co and Fe-base superalloys although a few special aspects of titanium applications were also included. To avoid difficulties with sensitive defence-related topics, the work was to concentrate on turbines for land-based applications such as power generation and oil and gas pumping. The latter have been particularly important growth areas for the industry because of the increasing demands of oil exploration. However, work on aero-engine materials was not excluded and formed a significant proportion of the total commitment.

The first Round of the Project was established in January 1973 and involved 67 individual programmes valued at 5.5 million ECU. This was followed by a second and third Round each with a similar level of effort. The participants have included the major companies involved in the building of gas turbines, supplies of components and alloys, as well as representatives of users, national laboratories, independent research organizations and Universities.

Management and coordination

The responsability for the management of the Project rested with the Management Committee which comprised two representatives from each signatory country.

The procedure for adopting a portfolio of research programmes involved several stages. These were a "call for proposals"; the scrutiny and assessment of outline proposals by the expert group; the request for full submissions from suitable outline proposals; scrutiny, assessment and final acceptance of the full proposals.

The original "call for proposals" was made against a set of guidelines drawn up by the Management Committee in consultation with the experts. This document defined priority areas where research effort was necessary.

Each proposal was carefully examined for:

- its technical merit, particular attention being given to the practical value of the work proposed and the research route envisaged by the applicant;
- the collaboration which the applicant had arranged and agreed upon with partners from other countries.

To help with the identification of suitable collaborators, meetings of the project leaders with similar interest were held so that work-sharing could be organised effectively from the outset. It has been generally agreed that meetings of this type were of considerable value to the participants and created a sense of belonging to a dynamic group with well-defined objectives and common goals.

A key feature of the development of the Project has been the active coordination of the work to ensure that work-sharing was effective.

Responsability for coordination has been assumed by the services of the Commission of the European Community.

Dissemination of information

In addition to the reporting procedures agreed between the participants, the Management Committee has encouraged publication of the work carried out in COST 50 in the scientific literature. The two major conferences held in Liège in 1978 (see references (1)) and 1982 (see References (2)) have established the European effort in gas turbine materials in the international scene. The original concept was that these conferences should be a counterpart to the US conference at Seven Springs.

In order to provide an appropriate technical structure for the Project the various research activities were grouped in coordination areas as follows:

1. Creep and Structural Stability
2. Fatigue
3. High Temperature Corrosion and Coatings
4. Casting
5. Weldings
6. Powder Metallurgy
7. Repair and Rejuvenation

At the outset the new high chromium alloys, specifically designed for the more corrosive environments of land-based and marine operation, were becoming available and a major activity was to obtain design and performance data on these materials. Alloy IN738LC was of particular interest and there was a need for long term data on, for example, creep performance consistent with the particular operating requirements for land-based turbines. The collaboration organised within COST 50 was

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NB. *References*

1. High Temperature Alloys for Gas Turbines, 1978, Applied Science Publishers, London.
2. High Temperature Alloys for Gas Turbines, 1982, Dr. Reidel Publishing Company, Dordrecht, Holland.

aimed at providing methods for obtaining such information, and long-term (100,000h) creep testing was shared between several partners. Subsequently the new alloy IN939 was introduced into the Project and the properties were characterised in similar collaborative studies.

Corrosion testing to assess hot-salt corrosion resistance using various test procedures including laboratory methods and high gas velocity rigs provided useful data but also revealed anomalies in the results obtained with the various methods. This led to an intensive programme beginning in the second Round of the Project to carry out an intercomparison using standard procedures and comparing the morphologies obtained with corrosion in service.

The combined effects of corrosion and mechanical deformation on alloy behaviour have also been examined.

The emphasis of the work on fatigue moved towards the problem of designing against low-cycle fatigue failure and a feature has been the intercomparison of the various predictive techniques. This was generally recognised as one of the most intractable problem in the design of plant for high temperature applications.

Among the more technological areas has been the commercial application of directional solidification for large blades with support from smaller scale experiments in the laboratories. A recent development has been the combined effort, involving United Kingdom, Belgian and French participation, to improve the recyclability of foundry scrap in the investment casting of high strength alloys.

1. Creep and structural stability

The work in this area had focused on the degradation of material structure and thermo-mechanical properties, mainly creep strength, as function of temperature, time, stress and strain. The main objective was to acquire a better understanding of mechanisms important for the use, maintenance, repair and life prediction of high temperature materials and components in gas turbines.

Useful progress has been made with studies on fracture mechanisms during creep and thermal fatigue and on studying changes during exposure at service temperature (700-900°C) up to 100,000h. This was linked with a study of the relationship between creep life and the nature of the potentially corrosive environment. Other individual studies which clearly progressed the subject were:

Individual studies

– fracture mechanisms during creep and thermal fatigue

- cavitation forming as a function of stress, temperature and strain,
- effects on casting parameters on structure of directional solidified material,
- creep under fluctuating load conditions,
- statistical evaluation of creep results using time-temperature parametric approach,
- consistency of high temperature properties of cast alloys compared to wrought,
- effects of coatings on mechanical properties,
- effects of castings conditions and over-ageing on creep performance,
- stress directed diffusion and pore growth,
- prestrain effect on pore growth,
- dimensional effects on creep rupture behaviour,
- coating and environment: effects of creep rupture behaviour.

Some of the more significant results were as follows:

- It is possible to recover creep properties and in some cases low cycle fatigue (LCF) properties of engine parts by reheat treatment. All accumulated damage can, however, not be recovered such as cracks, some cavitation and irreversible carbide formation. Creep rate can be entirely restored but not total elongation to fracture.
- Hot isostatic pressing (HIP) can be used to close pores and cracking and properties can be considerably restored. Also in some cases there is some irreversible structural damage which will not be regained by HIP. This is specially the case for Hafnium containing cast alloys where carbide composition will be altered and redistribution will occur at HIP temperatures.
- Segregation of alloying elements is considerable in cast alloys. The homogenization of composition occurring during heat treatment, hot working and service is irreversible and reduces to a limited degree the available creep life of some cast alloys.
- Cavitation has been studied extensively. Within 700-750°C cavitation at rupture is dependent on elongation but independent of temperature. Low stress gives more cavitation at rupture than high stress. There is a connection between cavitation and remaining elongation and time to failure.
- Tertiary creep and LCF are accompanied by continuous work softening, limiting the creep life of material and continuously increasing creep rate at constant load and temperature. This gives the material a finite life even if cavitation or crack propagation does not occur during creep testing.
- The factors creep rate, stress, strain and temperature can be related to

a single equation or presented in one diagram giving information about strain and strain rate at any given stress and temperature during tertiary creep once the basic parameters for tertiary creep have been determined.

- Life time prediction methods.

2. Fatigue

The field naturally divided itself into five subject areas namely:

- Low-cycle fatigue and creep, including fatigue interaction and the effect of specimen geometry on significance of test results;
- thermal fatigue, the effect of temperature on mechanism;
- high-cycle fatigue including the effect of the nature of the stress cycle, temperature and environment;
- fracture mechanics including the effect of small crack formation and damage accumulation;
- life prediction using the result of the above studies.

Basic understanding of the nature of fatigue damage was generated. Thus an improved method of predicting fatigue at high temperatures has been developed. This is based on a large amount of materials and mechanical property data. Again in the field of fracture mechanics at high temperature, new elastic-plastic concepts have been developed giving a basic understanding of the relation between the environment and high temperature crack-growth in superalloys. The applicability of crack-growth laws to complex geometries and loading conditions has also been studied fruitfully.

3. High temperature corrosion and coatings

One third of the total number of projects were concerned with corrosion, protective coatings and the interaction of these with mechanical properties. It was natural that this should be because of the direct and obvious relationship between these questions and the performance of gas turbines and the specifications needed to obtain the best possible materials of construction.

An important outcome of the activity has been the creation of a strong and broadly based European technological community in the field of hot corrosion. This has been based on a number of achievements, namely:

- considerable progress towards the rationalisation of corrosion testing

procedures. This did not fully achieve the objective of creating a standard testing procedure;
- a broadly accepted comparison of laboratory and engine experience for a wide range of industrially important alloys and coating;
- the emergence of one specific alloy, namely. CoCrA1Y with promising corrosion resistant characteristics;
- the demonstration of the importance of corrosion in affecting fatigue processes;
- the active inclusion in the collaboration of gas turbine users, turbine manufacturers, research institutes and academic groups, linking those concerned with fundamental studies and those with practical and commercial aims.

Seminars were planned to give the participants the opportunity to develop a restricted number of common themes. Three separate groups were established:

(i) coating development,
(ii) corrosion-testing methods,
(iii) corrosion-mechanical property interactions.

The most obvious gain made by this work in this area was the rationalisation of corrosion test procedures which probably owed as much to the fundamental electro-chemical and metallurgical studies of corrosion attack and diffusion of species at the metal surface as to the comparative operation of established testing methods in different laboratories.

A majority of the projects were concerned with different methods of evaluating the corrosion of samples of alloys using rig tests, laboratory exposure to simulated environments and electrochemical tests.

4. Casting

The initiative for this concerted activity came from the foundaries which were trying to solve the problem of absorbing increased quantities of revert materials without decreasing casting performance i.e. avoiding loss of stress-rupture properties at intermediate temperatures and also without detriment to the microshrinkage properties.

The project began with an empirical programme (identification of particular laboratory techniques) and this suggested that the nitrogen content gave a clue to the understanding of revert materials. Later work seemed to have made a valuable contribution to techniques by focusing on the need to limit the nitrogen content in revert materials. This could be achieved by modifying melting procedures as well as by selecting the scrap to be used. This work has made important steps towards substantial cost savings. Thus it was estimated that the full use of 100% revert materials for the production of IN100 alloy would produce savings of about 1.000.000 Ecus/year.

Foundries and users of cast components now understand better than they did before the activity began which critical components should be cast from virgin and which others could be cast with a high amount of recycled scrap.

Development and pilot plant experience of directional solidification of turbine blades has led to cooperation between foundries and the research centres.

5. Welding

The initial aim was to develop the application of welding techniques for the manufactures of gas turbine blades and discs from cast alloys. An early objective was to familiarize interested European partners with electron beam welding which had been developed and was apparently being used with confidence in the U.S. Good progress had been made in this sense and the COST 50 framework had encouraged the growth of confidence in Europe in the use of new welding techniques.

In fact, however, the most important result was to show that electron beam welding was not a suitable technique mainly due to the persistence of the problem of microcracks in the weld. The dissemination of basic understanding of the limitations was of clear value.

Two other advanced welding techniques were also studied though only at the laboratory level, namely inertia welding and diffusion welding. These avoided liquefaction and solidification which was the source of the risk of microcracks formation with electron beam welding.

The sharing out of work between participants has been very useful indeed for this type of research where equipment is scarce (diffusion welding) and materials to be used for samples extremely expensive.

The potencial outcome of the work is to make it possible to manufacture gas turbines both more cheaply and more reliably and at the same time to be able to use materials which offer better performance. Success in this sense would be of great financial value. In the rather negative sense of avoiding the use of inappropriate welding techniques —which is what the project achieved as a result of the study of electron beam welding— there is also important cost savings.

6. Powder metallurgy

The major objective was the selection of fabrication parameters to achieve optimum mechanical properties of the gas turbine component. Grain size control attracted particular attention as did dispersion strengthening alloys. The recent launching of two other programmes, i.e. COST 503 on powder metallurgy and the cost-shared basic Technological Research programme could also affect the available effort in the field of specific application of powder metallurgy to gas turbine plant manufacture.

7. Repair and rejuvenation

The intention was to provide a forum for the discussion of research progress being made in different coordination groups which had an immediate and potentially useful and cost-saving bearing on the repair and rejuvenation of gas turbine blades and other components. The activity was concerned with creep and structural stability and with welding.

Seven partners came forward including three major turbine manufacturers, two research institutes and two materials service laboratories.

Three main areas of interest are:

(i) the evaluation of the practical performance of repaired components of land-based turbines. This became a well-coordinated programme of sample testing for tensile strength, stress rupture and fatigue of repaired parts as well as the observation of the special susceptibility to corrosion of repaired components.
(ii) a study of the reasons for changes in properties during service, e.g. creep cavitation, and the mechanism of recovery and rejuvenation by HIP. This required the study of methods of simulating in the laboratory damage to service-exposed parts.
(iii) the development of practical repair techniques by brazing, welding, crack cleaning and diffusion bonding.

The idea had come mainly from gas turbine users who were no longer satisfied with empirical methods of damage repair and who turned to COST 50 as a vehicle for progress.

Cost project 501

Towards the end of the second Round of the COST Project 50 it became apparent that its limitation to materials for gas turbines was irksome. It precluded the possibility of extending the Project to involve new aspects of high temperature technology especially in the use of materials, both metallic and ceramic, in the highly corrosive conditions associated with coal conversion technology in particular and, indeed, in energy production and conversion in a wider sense. Specific objectives were identified, namely:

1. to meet the need for materials to permit the use of fuels with increased impurity levels;
2. to permit operation of equipment at higher temperatures to improve process efficiency and save fuel;
3. to achieve a more economic use of expensive alloys, especially those containing significant quantities of strategic elements;
4. to develop better methods of estimating the useful life of components so that expensive capital equipment could be maintained in service for longer times.

160 proposals were received for work on this project. 107 projects were approved and are now running, the research works will be completed by the end of 1986. The estimated financial expenditure for the three years action is in the region of 30 million Ecu.

In order to provide a basis for the synergoistic benefits to be obtained from a well organised Project unfolding concerted action, it was necessary to establish an appropriate structure for collaboration between partners individual projects (see below list of Projects) have been grouped in the following categories:

1. Oxide dispersion strengthened (ODS) alloys
2. Life time prediction
3. Gas turbine and discs
4. Corrosion and coatings in gas turbines and diesel engines
5. Coal conversion technology
6. Steam turbines
7. Data bank activities

1. ODS ALLOYS

The ODS group comprises of 23 individual projects most of which deal with Inconel MA 6000 from the same powder batch. Round-robin testing and work-sharing in the areas of creep and fatigue testing have been taken up.

Stress rupture tests, texture analysis and fatigue crack growth have been carried out under selected conditions. Creep damage has been analysed and found to support a theoretical model for creep fracture developed before.

First LCF results are available. Creep crack growth has been measured as a function of orientation and thermal fatigue has been investigated. Round-robin testing for creep has been completed and the results show reasonable agreement. The effect of contaminated hot gas on creep and LCF is being studied, and results on MA 754 have been obtained.

Progress has been made in bonding ODS superalloys. First experimental ODS alloys have been produced and the cross-over in strength of the fine-and-coarse-grained material determined.

2. Life time prediction

The various programmes were grouped under the following headings:

- Creep and creep damage
- Fatigue and fatigue damage
- Multiaxiality
- Fracture mechanics
- Alloy development
- Non destructive methods
- Empirical life prediction
- Data bank

Round-robin tests for uniaxial and multiaxial creep were performed. It was clear that the good collaboration which existed was due to there being the link of a common material i.e., IN 800H for a high percentage of programmes.

3. Superalloys, discs and blades for gas turbines

The situation of the different subjects coordinated within the group is described briefly below.

Long-time Satbility of Inco 718

The influence of upsetting conditions and of the thermal treatments on microstructure and properties has been considered.

Casting & Properties of Directionally Solidified Industrial Gas Turbine Blades

The size of the blade for this application (height 300mm, weight 3kg) causes difficulties for a DS part and the strength of the mould is a problem. Casts of good blades in Inco 738 have been produced and mechanical and corrosion tests will be carried out.

Powder Metallurgy for Discs

Rotating electrode (REP) powder in Astrology was produced in pilot plant using 155mm electrodes at a speed of 7000 t/mn. In comparison with argon atomized (AA) powder, the particles are larger, less variable in size and cleaner. Data for the analysis of the titanium content suggests that the REP powder are less homogeneous than the AA ones. Future work will consist of examining diffusion during the compaction and determination of the mechanical performance of optimized compacted products.

Rejuvenation of Turbine Blades by HIP

The programme includes studies on Inco 738 cast bars in phase 1 and on turbine blades having worked more than 10,000 hours on gas turbines in a phase 2. The aim is to determine the optimum HIP and heat treatment procedures to recover the creep properties. Samples machined from bars cast by Microfusion were "hipped" in the UK with different sequences and heat treated; these are ready for creep tests and for metallographic examination.

Amorphous or Microcrystalline Alloys for Brazing High Temperature Nickel Alloys

Ductile foils of special alloys for brazing can be produced by rapid cooling on a rotating wheel which gives amorphous or microcrystalline structures.

Development of nickle base alloys for brazing Inco 718 and for ODS alloys has been carried out and thin foils produced. Filler alloys brazed at 1010°C with good wettability have been developed.

4. Corrision and coatings in gas turbines and diesel engines

A major aspect of the work of this group is concerned with the development and assessment of thermal barrier coatings for blades, valves, combustion chambers etc. This is a rapidly developing area of Technology in which organisations in the USA are highly active. The work-sharing arranged by the COST 501 participants should enable European companies to keep abreast of developments elsewhere.

5. Coal conversion

The Group, which has 25 projects, has developed close, interwoven collaboration and achieved a distinct identity. The projects divide into three basic sub-groups namely; alloy development, gasification and fluidized bed combustion (FBC), but collaboration frequently occurs across the groups, particularly of course from those producing alloys or coating to those evaluating them.

Significant progress is now being reported from most of the projects in the three sub-groups. Those developing alloys and coatings have generally been able to supply collaborators with their first samples and many of the initial exposure results are already known. Most of the gasification groups are concerned with the identification of materials and corrosion rates in environments relevant to the raw gas heat exchanger of a gasifier and are concentrating on metals able to operate in the 400-700°C range. The FBC project are similarly concentrating on a single problem; in this case, that of erosion and erosion-corrosion of in-bed tubes. Whilst the gasification projects are predominantly laboratory simulations, several of the FBC projects include examination of the behaviour of materials exposed in pilot and commercial plants as well as laboratory experiments.

The activity is thus concentrated on two of the major technology-limiting problems of advanced fossil fuel combustion plant.

6. Steam turbines

The projects coordinated within this group are based on the following alloys:

- 9-12% Chromium-steels
- NiCrMoV-steels for steam turbine rotors
- heat resistant nodular cast iron

For the most part work is progressing satisfactorily and according to plan and this is particularly true for the sub-groups concerned with NiCrMoV steels and nodular cast irons.

7. Data bank activities

In order to allow the storage and subsequent evaluation of the relevant data generated by COST 501 projects, the HTM data bank project has carried out a number of adaptations and some of the main features are summarised below:

1) Following the evaluation of an inquiry among COST 501 projects into the types of data which become available, the data bank scope was considerably extended to accept these.

2) New data collection forms were designed to format data for this extended scope and to improve the user-friendliness of the data collection procedure. The work on the production of these forms is still going on.
3) Application programmes were implemented which allow statistical and parametric evaluation of data stored in the bank (the standard evaluation programmes).

Some conclusions on COST activities on high temperature materials

Information on and understanding of processes has been obtained by the combined use of resources not available to a single unit.

Starting from a position in which European users and manufacturers were of the opinion that U.S. firms and research centres were far ahead with new developments, COST has generated a community of European activity which is at least equal in achievement to those in the U.S.

Industry, research institutions and academic centres have been attracted to COST 50 participation in very satisfactory numbers and proportions. There had been early problems with bringing industrial adherents into full collaborating involvement especially with those forms who have relied upon proprietory know-how, confidentiality and patenting, but these problems have been circumvented in most cases.

An important contribution to the success of COST has been the way in which basic research carried out for the main part but not always by academics and institutes has been easily harnessed with industrial research and development. This has been greatly facilitated by the formation of closely-linked groups around well defined objectives and by the holding of seminars and conferences directed to settling specific questions.

There has been a continuous and progressive establishement of links between experts and participating organizations.

The rules for exchange and confidentiality of information have been successful and what is more important have been respected. This has led to a freer exchange of information on materials and their properties than would have occurred without the personal contacts and confidences established between researchers in the COST activities.

COST has created significant savings for the European gas turbine industry as a whole and for industrial firms. In particular mention could be made of:

(i) cases where the availability of resources and the sharing of testing procedures has shortened the necessary working time when delays in delivery of materials and failures of equipment have occurred.
(ii) The increased knowledge obtained on the properties of superalloys is now, of course, being utilised in design and, as a result, more

reliable components and engines are being builts. Much more is now known about the recylcling of superalloys scrap and the maintenance of material properties in reverted material. This has enabled considerable savings to be made in terms of strategic resources as well as the obvious financial benefits of not requiring wholly virgin melts of materials.

(iii) One area which show marked benefits in overall cost savings in the future is the protective coating of superalloy blading. In turbines burning low grade fuel component design lives are likely to be achieved only by the use of suitable corrosion resistant coatings. Coatings are now available and are currently being run in engines which may enable this objective to be realised. If successful, the cost savings will be significant in terms of raw materials and energy used in blade manufacture as well as in enabling operators to use the cheaper low grade fules without significant penalties being incurred in terms of engine life and reliability.

COST ACTION 503 "POWDER METALLURGY"

The basic considerations and the objectives of the project have been:

- to provide opportunities for cooperation between the industrial and research organisations in Europe (of which there are more than 100 engaged in powder metallurgical processing, technical development and research work.
- to support and coordinate these activities and to improve the comparative position of the worksharing
- to provide collaborative research on a wide range of topics of particular relevance to the industry.

You can see below the schedule of main activities.

Participants	:	Austria, Belgium, Denmark, Federal Republic of Germany, Netherlands, Finland, Sweden, United Kingdom
Duration	:	1984-1988
Number of Projects	:	58
Main Activities are	:	

1. *Powder Metallurgy of Light Metals and Alloys*

- powder production by inert gas and atomisation
- powder compaction and extrusion preevaluation of mechanical properties, microstructural investigation

- fatigue testing of ODS and RS alloys extrusions and forged parts
- alloy Ti-6AL4 investigation with respect to different powder sources and various techniques of consolidation.

2. *Powder Metallurgy of Hard Materials*

- *Ceramics Materials*

  - densification and evaluation of Boron Carbide
  - preparation and evaluation of special samples from cemented carbides
  - development of sample evaluation methods and application to special fine grained aluminas

- *Hard Metals and Heavy Alloys*

  - preparation and characterisation of cemented carbide parts from recycled powders
  - impurities in cemented carbides and their influence on technological performance
  - characterisation of carbide powders (WC, TAC, NBC, HFC) and their influence on the mechanical and technological properties of WC-CO and mixed carbide hard metals
  - effect of trace elements on metallurgical and microstructural features on sintered and deformed heavy metals

3. *Powder Metallurgy of Fe-Base Alloys*

- HIP of highly corrosion resistant alloys
- HIP processing
- fatigue design of connecting rods
- optimisation of heat treatment
- processing with binders
- complex parts by joining
- heat resistant parts by joining
- high performance gears
- near net shape high speed steel

COST ACTION 504 "CASTING TECHNOLOGY"

Castings have great potential with respect to producing complicated parts in one piece using less energy and less raw material. These are the main reasons for the revival of the casting industry in recent years.

However, the potential can only be exploited to its full extent if the casting are high quality products. Thus there is considerable scope for a strong effort on an international basis in an area which is vital to the manufacturing industry.

The objective are to promote medium to long term research with strong industrial motivation and potential for intereuropean collaboration and more specifically:

– provide opportunity for co-operation between industrial and research organisations in Europe
– improve working conditions by improving technology
– improve the competitiveness of this industry
– provide collaborative research of particular relevance to industry in a wide range of topics such as
  • direct casting processes of close to final shape products
  • productivity and quality of ferrous and nonferrous castings
  • metallurgical factors affecting casting technology and properties

The areas of activity are notably:

1. Improved properties of SGI
2. Modelling SGI
3. Solidification of cast alloys
4. Repair welding of Al-castings
5. Weld materials for creep resistant steel castings
6. Cracks in continuous castings of non ferrous alloys
7. Impurities, castability and properties of Al-castings
8. Squeeze casting of Al-alloys
9. Fibre-reinforced Al-pistons
10. Cast Al-blades for ventilators
11. Zn-Al Casting Alloys
12. High strength Al-alloys
13. Grain refining of Al-alloys

Participants to the action are:

Austria, Belgium, Federal Republic of Germany, Netherlands, Switzerland, Finland, Sweden, United Kingdom and CCE.

Duration of the action is 1984-1988, and the number of projects is 46.

COST ACTION 505 "STEAM TURBINE MATERIALS"

Consumer preference for electricity as a clean, versatile energy source has been clearly demonstrated in recent years and increased electrification of industry is inevitable. Electricity has unequalled ability to speed up automotion and increase productivity, and new microprocessor technology will increase that ability even further. The competitiveness of industry will thus depend in growing measure on the price of electric power. Whilst a number of ways of producing steam are available; eg. by burning coal or oil by the fissioning of uranium in reactors cooled by water or CO_2, the steam turning heat into electricity. Efficient steam turbines are, therefore, a cornerstone of prosperous economies.

In the last forty years or so, European power producing industries have made a large investment in materials research in improve the efficiency and reliability of steam turbine plant. However, many problems remain. Some of these are associated with the steady growth in unit size of turbines which leads, in particular, to requirements for larger forgings and casting, with associated problems of quality and properties. Furthermore, the use of high output units leads to very high costs of outages (plant shut-down) which results from unplanned repairs when component failure occurs.

For the same reason there is pressure from the utilities to increase times between scheduled maintenance periods. The efforts to improve component reliability and thereby to reduce direct operating costs. Other problems arise as a consequence of the changing circumstances in which the electricity generating industries in many indsutrialised countries now operate. For example, an elderly plant originally designed for base-load operation has frequently to be used for peak-lopping with rapid start-up and shut-down which can be highly damaging to critical components. The lifetime of plant working in this way cannot readily be estimated. Also, benefits in increased efficiency resulting form higher operating temperatures, particularly in the smaller industrial turbines, and from novel design concepts place new demands on traditional materials and provide the incentive for the development of improved alloys.

In addition, a major interest has developed in determining the remaining life of existing elderly power plants. The capital costs of installing new equipment is extremelly high and it is generally recognised that the design methods used 10-20 years ago were conservative, perhaps very conservative.

Consequently there is every likelihood that a plant designed for a life of 20 years will last much longer but it is an important and demanding task to accurately predict the increased length of service that can be tolerated with safety. Hence the problem of estimating remaining life in critical components of steam power plants has become a material problem of major importance worldwide.

For these technical reasons, therefore, materials research remains an essential requirement.

The programme is strongly supported not only by the countries with significant steam turbine manufacturing facilities but also by those without an indigenous industry that use steam power plants manufactured in other countries.

The basic considerations in the description of the Project have been:

- to provide opportunity for collaborative research on a wide range of topics of particular relevance between steam power plant manufacturers, users of steam turbines and alloy producers;
- to support and coordinate these activities to improve the competitive position of the industry;
- to provide a better exploitation of te existing elderly power plants by an improved basis for the estimation of remaining life in conservatively designed turbine equipment.

The research activities are mainly:

1. *Stress corrosion, high cycle fatigue and corrosion fatigue*

- concerned with stress corrosion cracking (SCC) in LP rotors and also with cracking in blade materials and assessment of new steels developed for this application.

2. *Remanent Life*

- programme on the characterisation of materials after long exposure in service conditions. The aim is to produce a data bank on time-expired materials to improve the reliability of remanent life assessment in plant.

3. *Materials for bolts and rotors*

- behaviour of Nimonic alloys and ferritic steels for bolting applications and characterisation of a rotor forging from a new type of steel.

4. *Creep fatigue interactions, welds and weld metals*

- on materials with major importance in steam turbine technology.

5. *High temperature crack propagation and fracture mechanisms*

- examination of correlating parameters for crack growth in ferritic steels
- non destructive testing of large components.

CERAMICS R&D WITHIN THE RAW MATERIALS RESEARCH PROGRAMME

The following table lists the general subject areas. With a few exceptions, most of the projects are concerned with materials development and processing. The materials range from improved refractory products to advanced technical ceramics, with emphasis on the latter both in terms of level of funding and number of projects.

Work on advanced refractions mainly involves research on the use of sialons for refractory applications.

Table 1

Subject

Silicon nitride-based ceramics
Silicon carbide-based ceramics
Zirconia-based ceramics
Alumina-based ceramics
Dispersion-strengthened composites (A1203/ZrO_2 mullite/ZrO_2)
Fibre-strengthened composited
Study of wear Nondestructive testing
Component testing

In the area of advanced engineering ceramics there are projects on silicon nitride based ceramics, silicon carbide, alumina, zirconia and composites. The work on silicon nitrides includes a research effort on production of powder by nittriding of silicon and carbon reduction/nitriding of silica.

Research on silicon carbide is less concerned with materials development but rather with an optimization of the injection molding technique for the production of turbine components.

Work on partially-stabilized zirconia is focused mainly on production of powder and their subsequent evaluation with respect to sintering behaviour. Complementary work is geared towards production of zirconia components for diesel engines from commercially available powders, as well as the production of thermal barrier coatings for the same application.

Production and characterization studies of dispersion-strengthened composites based on zirconia are proceeding.

Development of composite materials based on ceramic fibres is also receiving increased attention in Europe.

The importance of the availability of non destructive testing methods for the commercial success of advanced ceramics is also widely recognized.

Finally, there are two projects which are dealing exclusively with the evaluation of the performance of ceramics. One is a cooperative study on wear of, in particular, silicon-based ceramics. A special diesel engine for scientific evaluation of ceramic components was developed. The present raw materials program is scheduled to finish in 1986.

Another action on advanced materials (EURAM) is ready to start now. Engineering ceramics and ceramic-based composites feature some of the three priority areas in this programme with emphasis given to processing quality control, joining and wear.

The development of advanced high-temperature technologies is linked directly to process in materials research and development. Relevant areas in energy and industry include power generation and utilisation, petrochemical processing, automotive, mechanical and nuclear engeneering. Improved materials would allow increased efficiency, design life, reliability and safety in high temperature process plant and the use of lower grade fuel.

HTM at Joint Research Centre, Petten

The High Temperature Materials (HTM) programme has a recognised standing in the European high temperature field, playing a central role in providing information and promoting R&D of engineering materials.

The new programme is tailored to the technological needs for materials for long term service in high temperature aggressive environments by promoting, coordinating and conducting studies to evaluate materials behaviour under conditions relevant to critical areas of industrial processes. It thus provides a scientific service, concerned with materials information, data handling, and direct research programmes.

The programme activities are divided between five closely connected projects.

- Studies on Steels and Alloys
- Studies on Sub-Components
- Studies on Engineering Ceramics
- HTM Data Bank
- HTM Justification Centre

1. Studies on Steels and Alloys investigate selected HTM for their suitability for service in aggresive environments containing sulphur, oxygen and carbon by means of experimental studies to obtain an understanding of the mechanisms causing alteration in properties and failures of samples by corrosive attack, creep or fatigue acting singly or in combi-

nation. The mechanism of protection of alloys by corrosion resistant coatings is also investigated.

2. Studies on Sub-Components verify experimental methods of applying laboratory property data to tubular sub-components operating under complex conditions of creep/corrosion, improving engineering methodologies for the analytical prediction of stress, deformation and life of components operating at high temperatures.
3. Studies on Engineering Ceramics involve the programme directly on a new scientific field. Development of new materials during the last decade has regenerated interest in the feasibility of exploiting the advantages of ceramic components in high temperature corrosive structural applications. The problems remain essentially those of fabrication, and of materials reliability in service. The project contributes to both of these areas, by developing methods for obtaining and optimising the mechanical properties of selected engineering ceramics.
4. The HTM Data Bank scope covers properties of a range of important HTM. The data bank promotes coordination and standardisation of data information and will be available on-line or indirectly to all European Community users.
5. The HTM Information Centre aims encourage information exchange, to collate and distribute materials information, to identify and evaluate future R & P requirements and to promote interactive research collaboration in the HTM community. The Centre provides a service concerning all aspects of high temperature materials applications from industrial manufacturing to academic research.

Up to 1984 the programme focused attention on metallic systems and coatings. With the starts of the 1984-87 programme period an additional project on enginnering ceramics was initiated, in recognition of the greatly increased prospects of widespread industrial exploitation of these materials. The primary objectives of this project are to clearify the mechanisms by which advanced engineering ceramics deteriorate in dynamic, mechanical and corrosive environments and to develop guidelines for material improvement. The project is formally organized along the following lines:

i) Study of the high temperature corrosion mechanism of engineering ceramics.
ii) Determination of mechanical behaviour in high temperature corrosive media.
iii) Establishment of the interdependence between processing parameters, microstructure, and corresponding properties.

BRITE
THE COMMUNITY PROGRAMME OF RESEARCH IN INDUSTRIAL TECHNOLOGIES

The BRITE programme (Basic Research in Industrial Technologies for Europe) was adopted by the European Community on 12 March 1985 with Community funding of 125 million ECU for the period 1985-1988, to which industrialists will add an identical sum.

The programme aims to stimulate the development of a solid foundation of advanced technologies to support traditional Community Industries. More specifically, the aim is to promote the development in industrial technologies of a tradition of transborder cooperation between firms, universities and research institutes, by encouraging them to work together on certain particularly promising projects.

The BRITE programme covers "precompetitive" research, an intermediate stage between fundamental research and development work immediately preceding marketing.

The BRITE programme objectives are:

- to stimulate European industry to equip itself with the technological base necessary to regain its competitiveness;
- to act as a catalyst for technological research be creating the conditions for bringing together research institutes across the borders of the Community Member States.
- to encourage cooperation between firms and research institutes across the borders of the Community Member States.

The area of activities are:

1. Reliability, wear and deterioration
2. Laser technology
3. Joining technologies
4. New testing methods, including non-destructive testing on-line testing and computer-aided testing
5. Mathematical modelling
6. Polymers, composites, other new materials and powder metallurgy
7. Member science and technology
8. Catalysis and particle technology
9. New production technologies suitable for products made from flexible materials

The BRITE programme is now actually under way.

- in January 1989 contact covering the first seven of 95 projects selected

were sent for signature by the partners involved and all the corresponding research work shortly be in progress
- the first tranche consisting of 95 projects selected from the 559 proposals received following a call for proposals represents a total of some 120 million Ecu, half of which is contributed by the Community
- the projects involve 432 organisations from all Member States, i.e. a little over four organisations per project on average. The organisations can be broken down into 60% industrial firms (including 24% small and medium-sized firms), 21 research institutes and 19% universities.
- the programme involves nearly all the main industrial sectors, e.g. motor industry, aeronautics, chemicals, textiles, metalworking etc.

The second tranche of the programme will start in autumn 1986. The call of proposals will publish an Official Journal of European Communities in May/June 1986.

EURAM

The EURAM (European Research on Advanced Materials) programme aim to combine basic materials research with the "engineering" development of advanced materials upstream of the manufacturing industries, in order to help raise the technological level of their products and thus help them compete better on world markets. This means the creation, development and use of new materials and the upgrading of more conventional materials to a higher level of sophistication.

In more general terms the EURAM programme takes into account the existence of the national programmes in order to provide cohesion between complementary activities. Furthermore, any duplication of research projects between EURAM an BRITE will be avoided by the Commission services.

LIST OF MAIN R & D TOPICS

Metallic materials

Topic 1 : Aluminium alloys

Aluminium and its alloys are already well developed yet they still offer much potential for development - especially in transport (aerospace, automobile) where the ratio of mechanical properties/specific weight plays an essential role.

Development could follow these three lines:

1.1 Further development of conventional aluminium alloys to achieve greater performance and reliabilty
1.2 Development of new powder-metallurgy aluminium alloys
1.3 Development of superplastic Al alloys

Topic 2 : Magnesium alloys

2.1 Development of new Mg alloys having improved characteristics
2.2 Improvements to magnesium alloys coatings
2.3 Development of a new range of rapid solidification (RSR) magnesium alloys

Topic 3 : Titanium alloys

3.1 Simplification of titanium alloy preparation via the direct reduction of mixed oxides
3.2 Metallurgy of high-performance titanium powders and alloys
3.3 Technology of semi-finished products and fabrication of titanium-alloy components

Topic 4 : Electrical contact materials
Topic 5 : Magnetic materials
Topic 6 : Coating and tooling materials
Topic 7 : Thin-walled castings

Engineering ceramics

Topic 8 : Optimization of engineering ceramics
Topic 9 : Metal/ceramic interface
Topic 10 : Composite ceramics
Topic 11 : High-temperature behaviour of engineering ceramics

Composite materials

Topic 12 : Organic composites
(a) Thermoplastic matrix
(b) Thermo-setting matrix

Topic 13 : Composites with metallic matrix
Topic 14 : Other advanced materials for specific applications

The funding of proposals to the programme was 35M Ecus for a 4 year period (1986-1989).

The call of proposals will probably be publish on the Official Journal by the second half of 1986.

Component development for advanced power engineering systems a new approach to European collaboration in power engineering technology

In attempting to define a future strategy for collaborative research to power engineering in Europe has recognised the need to build on the success already achieved and to exploit the framework of collaboration established within the European industry.

The urgent need in materials research in power engineering is for a programme of pre-competitive research which is closely targeted on the critical needs that must be met if advanced plant is to be designed and built successfully for the next century. Discussions with design and development engineers in the European industry have helped to identify key areas in the development of advance power engineering systems that are materials limited. In other words, until certain components with specified performance capabilities are available there can be no significant progress in systems development.

The key essential basis of the programme will be the identification, in consultation with design and development engineers, of the performance requirements and component capabilities that must be achieved in the continued development of power engineering plant and equipment.

It is envisaged that the research involved in the "work-packages" would be carried out in the main by the alloy users and producers.

The work packages will concern

- blades and valves for advanced industrial gas turbines
- high pressure discs for advanced gas turbines
- rotors for use in high temperature steam
- heat exchanges for coal conversion technology etc.

A guide of hot corrosion control and materials used for gas turbine airfoils

The aim of this work is to show how to decrease and mainly how to control hot corrosion processes by which blades and vanes of hot sections in gas turbines are affected.

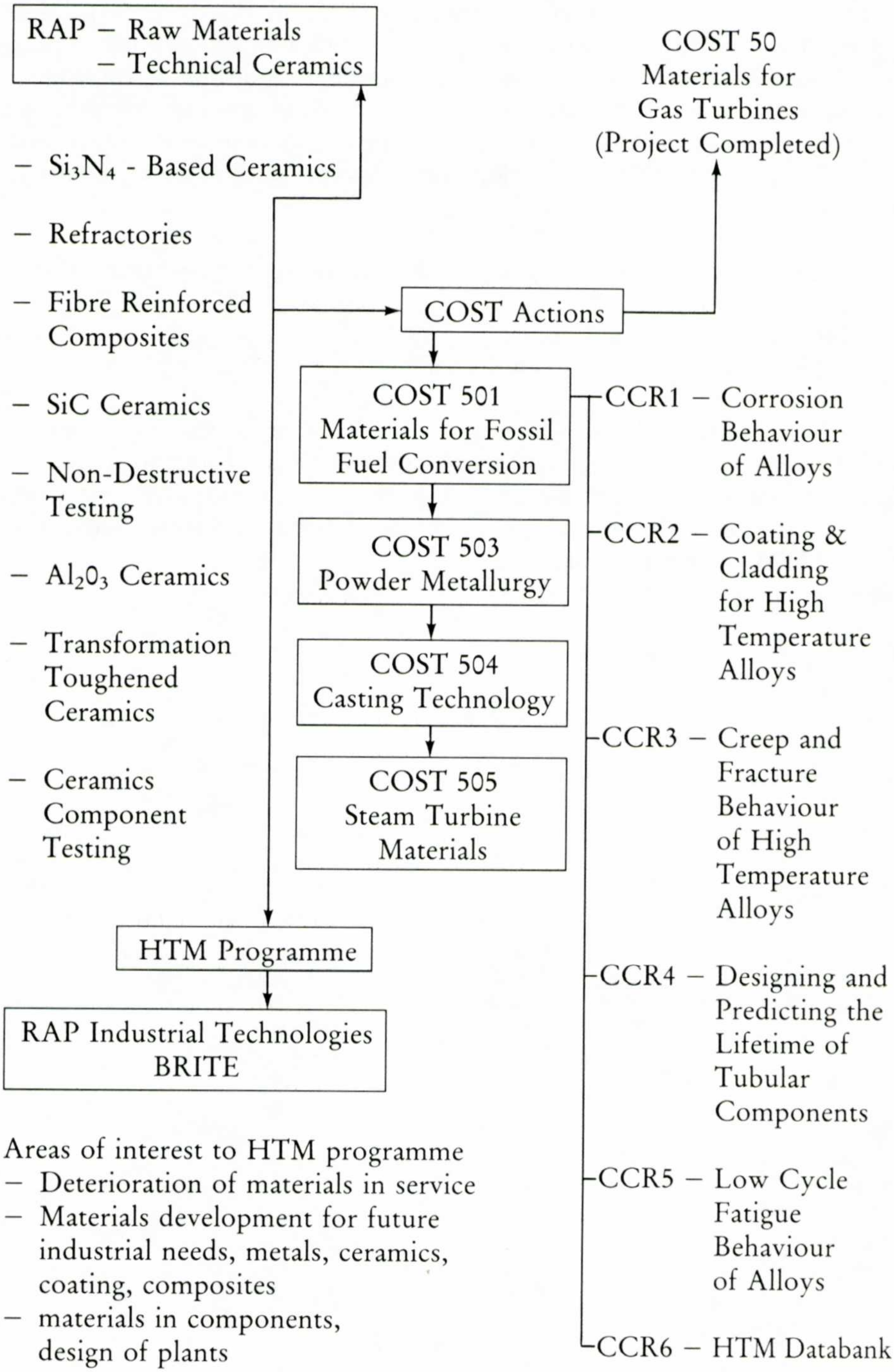
In hot sections of gas turbines, the components (blades and vanes) are subjected to severe mechanical as well as environmental stresses. The most critical parts are first stage blades and vanes. According to the type of machine, its mission (aeronautical, industrial, marine turbines), these parts undergo different thermomechanical cycles and work in complex environments (combustion gases): in oxidizing conditions at high temperatures (T more than 1000°C) and/or in corrosive conditions with condensation of salt deposits on the components at immediate temperatures.

The materials that are developed for this application must, therefore, exhibit:

- high mechanical strength at elevated temperatures (creep, thermal and mechanical fatigue);
- high microstructural stability;
- high oxidation and corrosion resistance.

For the user who has to face the problem, it is first important to identify the specific type(s) of corrosion that are responsible for the main damages (temperatures of the blades - expertise on corroded components).

The guide will be edited by the Commission and presented to the next HTM congress in Liège.


RAP – Raw Materials
– Technical Ceramics
COST 50
Materials for
Gas Turbines
(Project Completed)
– Si_3N_4 - Based Ceramics
– Refractories
– Fibre Reinforced Composites
COST Actions
– SiC Ceramics
– Non-Destructive Testing
– Al_2O_3 Ceramics
– Transformation Toughened Ceramics
– Ceramics Component Testing
COST 501
Materials for Fossil
Fuel Conversion
COST 503
Powder Metallurgy
COST 504
Casting Technology
COST 505
Steam Turbine
Materials
CCR1 – Corrosion Behaviour of Alloys
CCR2 – Coating & Cladding for High Temperature Alloys
CCR3 – Creep and Fracture Behaviour of High Temperature Alloys
CCR4 – Designing and Predicting the Lifetime of Tubular Components
CCR5 – Low Cycle Fatigue Behaviour of Alloys
CCR6 – HTM Databank
HTM Programme
RAP Industrial Technologies
BRITE
Areas of interest to HTM programme
– Deterioration of materials in service
– Materials development for future industrial needs, metals, ceramics, coating, composites
– materials in components, design of plants