KERNFORSCHUNGSZENTRUM

KARLSRUHE

Dezember 1972 KFK 1713

Institut für Material- und Festkörperforschung

Application of Sintering Theory in Practice

Topics for Discussion
(revised form, including comments of ITS members)

F. Thümmler

GESELLSCHAFT
FÜR
KERNFORSCHUNG M.B.H.

KARLSRUHE

GESELLSCHAFT FÜR KERNFORSCHUNG M.B.H.
KARLSRUHE

KERNFORSCHUNGSZENTRUM KARLSRUHE

KFK - 1713

Institut für Material- und Festkörperforschung

Application of Sintering Theory in Practice *)

Topics for Discussion
(revised form, including comments of ITS members)

by

F. Thümmler

Gesellschaft für Kernforschung m.b.H., Karlsruhe

*) Prepared by the "Institut für Werkstoffkunde II der Universität Karlsruhe" as an invited paper for the discussion of the "International Team for Studying Sintering", Herceg Novi/Jugoslavia, September 6-11, 1971

Contributors to the discussion

F.	Thümmler	(Opening thesis)
I.M.	Fedorchenko	
M.	Tikkanen	
H.	Fischmeister	
T.	Erić	
C.	Majani	
V.	Mikijelj	
H.E.	Exner	
M.	Dvořak	
R.	Coble	
S.	Kiss	
K.E.	Easterling	
C.	Greskovich	
L.	Žagar	(Chairman's summary)

Other participants, took part in the oral discussion, namely G.S. Tendolkar, E. Labusca, A.L. Stuijts, E. Navara, D.L. Johnson, I.B. Cutler, G.C. Kuczynski. Even though a recording of their remarks exists, the editors did not wish to print their contributions in the absence of a written text.

Preface

In Sept. 1971, the Second International Round Table Meeting, organized by International Team for Studying Sintering (ITS) was held in Herceg Novi, Jugoslavia. Almost the whole material of this meeting is available in written form, mainly as preprints, excluding the discussion until now. A Russian edition of the papers is now in print.

One of the focal points was the session "Application of the Sintering Theory in Practice". As far as we know, this theme was not treated before in such a form. After an opening thesis presented by the author of this report, very lively discussion followed, Prof. Žagar, Aachen, being the chairman. Due to the broad interest of this theme the secretary of ITS as well as the author found it worthwhile to publish this session with the part of discussion available in the written form. It perhaps will stimulate further work and achieve a better understanding as well as closer cooperation between theoretical and practical people in powder metallurgy and ceramics.

Vorwort

Im September 1971 wurde das 2. Internationale Round Table Meeting, das vom International Team for Studying Sintering (ITS) organisiert wurde, in Herceg Novi, Jugoslavien, abgehalten. Fast das ganze Material dieses Treffens liegt nun gedruckt vor, meistens als Vorabdruck, allerdings ohne Diskussionsbeiträge. Ein Tagungsbericht in russischer Sprache befindet sich im Druck.

Starke Beachtung fand u.a. die Sitzung "Anwendung der Sinterthoerie in der Praxis". Unseres Wissens wurde dieses Thema erstmalig in einer solchen Form behandelt. Eine sehr lebhafte Diskussion (Leiter Prof. Žagar, Aachen) folgte dem Eröffnungsvortrag, der vom Autor dieses Berichtes gehalten wurde. Auf Grund des großen Interesses an diesem Thema hielt es das Sekretariat des ITS wie auch der Autor für angebracht, den gegebenen Bericht sowie den schriftlich zur Verfügung stehenden Teil der Diskussion, zu veröffentlichen. Hierdurch könnten weitere einschlägige Arbeiten angeregt und ein besseres Verstehen wie auch eine engere Zusammenarbeit zwischen den mehr theoretisch und den mehr praxisbezogenen arbeitenden Pulvermetallurgen und Keramikern herbeigeführt werden.

Work about theories of sintering or - more generally - the process of sintering may be undertaken with at least two objectives:

a) for a better understanding of the sintering process and to develop better theories,

b) to get improved sintering conditions and/or better sintered products.

The sintering process of metallic and nonmetallic materials has been investigated in many laboratories for a long time and numerous papers have been published. We now understand most of the phenomena occuring during sintering, in many cases only qualitatively. In this extremely complex field, some things are still not generally understood. In some cases, theoretical work has influenced the practice to get better or special products. In spite of the considerable success that researchers in the sintering field have achieved, several questions, mainly general in nature, have arisen during recent years, e.g. the following:

- What is our chance to get a generalized theory of sintering?

- What kind of experiments do we need to move in this direction?

  and, last not least,

- What is the practical value of all the sintering experiments that have been done so far, with respect to the many sintered products we know.

Naturally, the purely basic research has its justification at any time and in any field, but questions of this type cannot be avoided by researchers in the sintering field and have to be discussed. The feeling of many people engaged on sintered materials, especially in industry, is that a considerable part of the work done so far is hardly relevant to practice. There seems to be a gap between most of the work devoted to the sintering process (sintering theories) and the requirements of practical sintering processes in the powder metallurgy and ceramic field. For this reason some of the powder metallurgists or ceramists express some criticism of the more academic studies on sintering and find them unpractical. An attempt to change this situation would be worthwhile - at least partly - although it seems to be somewhat difficult. In this respect, the following topics should be discussed.

1. At the present time we do not have a general qualitative or quantitative theory of the sintering process, which is generally known and accepted as well as used in practice. Therefore the available voluminous material about sintering processes should be carefully and objectively analysed. Through such an analysis those of the existing theoretical considerations should be emphasized that can be used most probably for the development of an unified theory. A new and progressive idea put forward during recent years is the correlation between kinetic data and the electronic state in the solid material, i.e. the localized part of the electrons, forming stable configurations and a non metallic part of bond within the lattice. The bond in the lattice is the basis from which all data of atom mobility must be derivated at least in principle. Unfortunately, quantitative estimations and correlations are extremely complicated. Within all this work, important, reliable and logical facts must be stressed, specially those of more general validity and ability to contribute to the explanation of the sintering phenomena in practice.

2. Recommendations should be made about theoretical and experimental methods and the type of experiments necessary to develop or improve the general theory. In this context the types of experiments used so far should be critically analysed with respect to their usefulness for present and future developments.

3. Even if we should obtain a general sintering theory, its broad applicability in practice will remain uncertain and doubtful. The state of, and the processes in, real powders, compacts and products during sintering are too complex and depend on many factors, which a general theory hardly can consider. This is not only true for the densification process, but especially for the development of mechanical and physical properties during sintering. These properties are very sensitive to influences other than the density itself.

   The motivation for a great deal of further work about sintering should be given therefore by practical problems to a greater extent than before. Sintering experiments should be performed mainly with real powders which must be well characterized, chemically as well as physically. Powder characterisation has to be improved generally. In special cases, the sintering of, say, idealized powders together with powders used in practice in the same experiment might be useful for the purpose of comparison and detection of influencing factors. Generally speaking, systematic investigations on technically applied systems, to deserver the most important factors should be helpful.

4. There are some processes or phenomena, that should be investigated in more detail, e.g.:

   - activation or inhibition of sintering
   - improvement or deterioration of mechanical and physical properties
   - improvement or deterioration of shrinkage tolerances
   - homogenisation in multicomponent systems.

In this respect little is know about:

a) the influence of all kinds of foreign constituents on sintering and development of sintered product properties,

b) the influence of all kinds of surrounding media (esp. sintering atmospheres) on sintering process and sintering product properties,

c) the conditions for getting sintered material with very small or well defined grain sizes, including grain and pore growth inhibitors,

d) the temperature and probably time dependent "effective" diffusion coefficients controlling homogenisation processes in multicomponent systems and their relation to such data, obtained in massive diffusion samples.

e) the phenomena and kinetics during the late sintering stages, as well as the effects of "oversintering", whatever that means.

These points are of vital interest for people in practice and this could be a main field of cooperation between industry and research facilities, in order to get systematic results on practically important systems and to apply important findings in practice.

5. We must consider that in many products fabricated from powders large shrinkage is not allowed and even the best shrinkage equation is not applicable for the sintering process. In such cases the main question is the development of the mechanical and physical properties during the sintering process at a nearly constant density or at a very low densification rate. Hence, the structural influences become of considerable importance. The influences may be summarized as those of microgeometry or stereometry of pores, grains, subgrains, phases and impurities and, on the other hand, of lattice defect structures. The dependence of product properties on such parameters has to be investigated in as much detail as possible.

6. During work on applied systems, close contact should exist between researchers and practical powder metallurgists. Sometimes it seems necessary to develop a "common language" between researchers and industrial people, at first to clarify the problems and then to solve them as well as to interpret the results.

7. There seems to be a certain mental gulf between powder metallurgists and ceramists, i.e. between people working with metallic and with nonmetallic materials resp. More work has to be done to compare sintering phenomena and theories for metal, carbide and oxide powders resp. or - more generally - powders with mainly metallic, covalent or ionic bonding. There is no doubt that ceramic and powder metallurgy workers are willing to discuss their results together to a greater extent than before, and that they are able to learn from each other.

8. It would be worthwhile, if researchers in the field of sintering draw practical conclusions from their theoretical or experimental work and give recommendations for utilisation of the results. This would help to minimize the gap between research and practice and to encourage the people in industry to test the results of researchers. Another possible way is that the researchers themselves work for a certain time in the powder metallurgy or ceramic industry, with a view to the application of their ideas or results under practical conditions.

It must be emphasized that the purpose of this paper is not to say that researchers in sintering have done nothing so far of value in practice, or that the powder metallurgy and ceramic industries are not interested in research on sintering. This would be really untrue. But perhaps it will encourage us to think about the problems of both theoretical <u>and</u> practical importance and people of both sides to get a little more in contact. It is necessary in any field of science and technology to envisage the <u>real</u> problems.

Discussion

I.M. Fedorchenko: It is possible to speak with confidence about the large contribution of theoretical studies in the sintering field in the powder metallurgy practice. Many examples from the activated sintering field can be mentioned. For instance, studies in that field, being done after observation of the activation effect, made it possible to apply methods of activation technologically during sintering of refractory metals and refractory compounds by introducing small quantities of additives. Theoretical developments in this field make a basis for choice of additives and methods of treatment, such as: the use of fine powders, the introduction of iron group additives, and sintering in vacuum. It became possible to come up with practically nonporous materials from carbides and borides of titanium, zirconium, niobium etc., porosity not exceeding o.5 - 2.o %, using temperatures below o.6 - o.65 of the melting temperatures. Sintering of borides was substantially improved by introduction of 5 - 15 % carbides of the same metal. It is possible to cite other examples too.

But the practice in the sintering field is going on ahead of the theory. Most of the technical processes have been worked out experimentally. Activation effects were observed in such a way, and have not been predicted by theory. Theoreticians undertake the work directed to generalization and explanation of existing experimental data.

In recent years, an notable advance was made in the direction of an understanding of the sintering mechanism. The role of structural defects became more and more clear and it is evident that a unique universal theory will be based on the solution of the problem of interactions of the structural defects in all their forms. The solution of this theoretical problem leads to an important approach to the solution of the practical problems.

M. Tikkanen: I am limiting my contribution to the metal powder industry leaving the oxide materials to our experts here.

You must understand that the P/M iron parts industry is not at all interested in such things as the densification process, since their parts must not shrink much, usually below 1 %. Their interest is mainly concentrated on the mechanical properties. They achieve the relative density they need by pressing, not by sintering.

Most of the investigations in this industry are technological ones, mostly carried out in the laboratories of the respective factories and there are not many possibilities for outsiders. Sintering is only a small part of their investigation field there being much more important things to study like powder qualities, lubrication of powders, pressing of powders, selecting suitable and cheaper sintering atmospheres and so on.

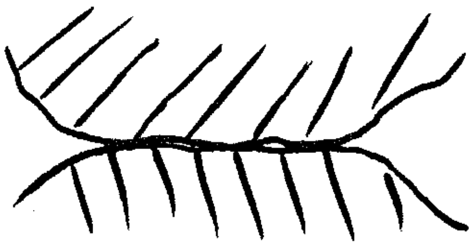
There are, however, some other areas where the theoretical studies of sintering, that is of densification, have been useful in industry. I have a good example from the heavy metal industry, where we some 15 years ago developed a phenomenological kinetic equation for following the densification of this product containing W, Ni and Cu, which equation is used even today. This is, however, understandable since the heavy alloy product must not have any porosity and, at the same time, have as small grain size as possible. This means that the sintering process must be controlled very carefully.

There is one more area where I believe that theoretical studies of the sintering process are of interest, i.e. the refractory hard metal industry. This industry which was closed against all outsiders earlier has now awakened and opend its door for scientists. The technical representatives of this industry begin now to understand that they most know much more of the scientific background of the fabrication process in order to be able to stay alive in the hard international competition.

H. Fischmeister: Let me sketch a few problems in the boundary area between sintering theory and practical iron powder metallurgy, the manufacture of sintered steels.

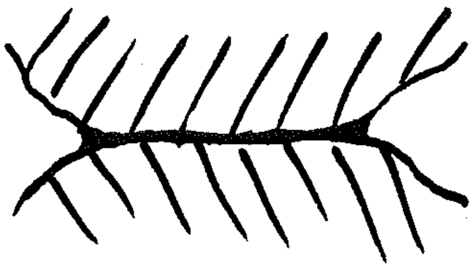
1. As already mentioned by Prof. Tikkanen, the aim of sintering is to obtain strength, by achieving a large amount of contact surfaces between particles, while avoiding shrinkage, which would endanger the mechanical tolerances. To reduce internal notch effects, sintering should be carried just far enough to allow some rounding of the pores, but not so far as to produce shrinkage. This can be done by favouring non-shrinkage-producing mechanisms, i.e. by additions of sulphur which enhances surface diffusion.

2. Practical powder metallurgy very seldom deals with unpressed powders. Pressing deformes the particles of ductile powders (like iron) to such a degree, that the actual contact geometry is really often more uniform than that of the original powder particles. A typical contact geometry is shown in Fig. a below



a.

Obviously very little material transport is needed to reach the degree of neck development which is most useful from the point of view of high strength but low shrinkage (Fig. b)



b.

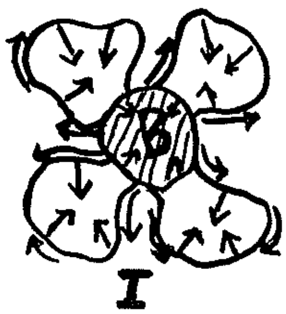
It would be easy and rewarding to modify existing sintering models so as to comply with a typical, realistic contact geometry.

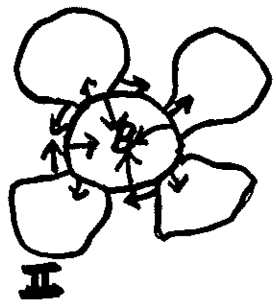
3. An important task then is to develope a valid statistical description of contact geometry in pressed compacts. This task appeared unsurmountable until recently, but today we have scanning electron-microscopy and quantitative metallography. It ought to be possible to develop methods of geometrical characterization using these tools.

4. Sintering of commercial iron powder compacts is never carried out isothermally. The development of an understanding of non-isothermal sintering and the role of various transport mechanisms in different temperature regimes is important in this connection. Much of this understanding is principally available today thanks to the work of Prof. Johnson and others.

5. Alloying is an important problem. In principle, alloying by diffusion, starting from elemental powders, could be cheaper than using pre-alloyed powders. Theories of homogenization by diffusion based on point contacts could easily be improved, using analogies with existing theories of diffusion controlled phase transformations.

The role of surface and grain boundary diffusion is very important. Two cases are found experimentally:





I. Fast diffusion of the alloying element B coats the surfaces of surrounding Fe particles, so that short paths only remain for volume diffusion.

II. Iron diffuses faster than the alloying element so that this particle has its surface coated by iron. In this case most of the alloying has to proceed by lattice diffusion, and alloying is slow.

Experimental studies of these conditions would seem valuable as a step to the practical application of sintering theory.We have talked a great deal about the difference between the idealized models of sintering theory and the real powder systems of practice, and the gulf that apparently separates them. Personally, I do not feel that this gulf is insurmountable - if we keep our objectives reasonable. I pointed out in the summary of the session on intermediate and final stage sintering, what we can expect from any theory is the prediction of trends in sintering behaviour and an understanding which will allow us to utilize or modify these trends.

Improved description of real compact geometries in pressed compacts, together with model studies on the influence of distribution of particle sizes (or more significantly, curvatures at contact points) along the lines suggested in this meeting by Coble, and further elaboration of the concept and the kinetics of particle rearrangement ought to make it possible to understand the behaviour of real powders in terms of the basic theories of sintering already developed.

Why should sintering theory be asked to give numerical predictions of engineering data for real systems if such predictions are not possible in any other field of materials technology? One of the greatest advances in alloyed steels was the introduction of the concept of hardenability and its connection with TTT diagram, around the forties. In the course of less then two decades these concepts had become second nature to every steel technologist. TTT diagram are used everywhere to discuss and understand the influence of alloying elements on the hardening of steels. Yet there is no truly valid method to calculate in absolute terms a hardenability curve from the contents of alloying elements in a real steel. This is not because such calculations would be impossible owing to a gap in our physical understanding but because it would be simply too tedious to construct a model comprising all the factors that can act in a real steel. Too tedious, that is, in relation to the small improvement that a complete solution would bring over the present practice.

T. Erić: I wish to congratulate Prof. M.M. Ristić and his colleagues for their efforts to connect theory and practice, so useful to this, our country that is not too rich. I would like to present a problem that can be interesting and is connected with the scope of this meeting.

Even though many papers concerning sintering have been published, until now we in the industry are not in the position to be able to use directly the results of these investigations. Basic raw material for refractory materials, $MgCO_3$, disappears and the question of the production of MgO from other sources, sea water or dolomites, arises. Deposits of dolomites are very rich in our country. MgO from sea water is very expensive: 300.000 tons of sea water for a ton of magnesite. The use of pure dolomite is very difficult, as is the addition of SiO_2 in the form of sand, which has many impurities. What intentions exist to study oxide systems, esp. activation of system CaO-MgO with low contents of impurity? For our use, introduction of additives is not allowed, and the studies concerning the influence of different additions on MgO sintering is unlikely to improve the production processes.

C. Majani: The tendency to study the sintering from the phenomenological point of view, I believe, can be seen as a kind of reaction to the impossibility of translating the theoretical and model studies into the solution of practical problems, in many cases. In my experience, this phenomenological picture helped much more to solve technological problems than some other theories of sintering, especially when only the density of body is concerned. For many purposes, e.g. the production of nuclear fuels for fast reactor and its economical improvement, we can not only regard the density of the body as being our goal. We have to take into account also the physical and the mechanical properties of these materials, since they influence strongly the in-pile behaviour of the fuel. This is necessary also for many other materials. In this case the phenomenological approach does not help very much.

I hope that an important contribution of ITS arising from Prof. Thümmler's contribution will be the redefinition of the goals in studying sintering processes, with respect to the important physical or mechanical properties as suggested in the introductory report. An effort should also be made to organize them.

V. Mikijelj: Considering the problems that we discuss, the question of common language has been already mentioned. I mean that it is an essential problem that has to be solved in order to use research results in the industry. One of the ways to find such a common language for the research people and professional staff in the industry is already mentioned by Prof. Tikkanen when be spoke about common work done by people from the industry and research. This method of establishing common teams working on problems that are interesting for industry, we also consider most promising. For that reason we introduced such working groups and we expect appropriate results. At the same time we can see here besides scientific research people, many participants form the industry. It is the evidence of their efforts to understand research language, and I think that efforts to understand language and needs of practice are highly desirable for most of us.

H.E. Exner: I do not think that one should blame only the scientists for the gap between technology and science. First of all, industry does keep most of its know how as a secret, and research work at the universities and other institutions starts at a quite low technological level. Secondly, the problems of industry are very seldom clearly defined to researchers. This brings about the lack in understanding and missing of important points. And finally, industry is scarcely interested in basic long term investigation, attractive for research institutes, since the results don't show up in financial success after a short time.

What I think would be necessary is a catalogue of problems important for technological progress. I am sure most of the problems would be taken up by research workers if well defined questions were put by the industry and the background necessary for effectively dealing with them were provided. I think this would be a task to be taken up by ITS and I would appreciate if this idea - which came up during the discussion in our institute - could be considered by the team. Publishing the problems in the Journal Physics of Sintering would guarantee the spread.

Dvořak: I would like to state some practical problems, which occur in industry with the sintering of ceramics.

Powder characteristics: The classical powder characterisations do not explain the different sintering behaviour of powders sufficiently. More attention should be paid to the chemical and crystallographic properties of the ceramic powders which can be influenced by the powder preparation process. Sintering behaviour and final results depend in many cases on the origin of the powder. During powder preparation the defect structure of the powder will be established. Defects in the crystal lattice seems to us to be the key for differences in sintering behavior and final properties of the sintered products.

Sintering: In order to press and sinter powders, they have to be prepared for the forming procedure. Water, organic additives etc., are needed, which can react with ceramic powder and influence the sintering behaviour.

Sintering in practice is mostly carried out non-isothermally. Heating rate, soaking time, a prefiring at lower temperature before final sintering at a higher temperature, can strongly influence density, grain sizes and strength of ceramic products. A better understanding of the influencing factors would be appreciated and should be investigated in detail by research people.

R. Coble: I feel that the models which exist are fairly accurate but should be tested critically in application. There is a basic need for data on surface and grain boundary energies and diffusion coefficients in dependence on impurities, additives, atmospheres and dislocations to utilize existing models in real systems. A phenomenological model for real systems might then be comprised of mechanistic models for the various stages of the process.

S. Kiss: During this discussion, importance of the study on models and connection between theory and practice was often pointed out. Up to date work done on models is very useful for obtaining general concepts about the process of sintering in single phase systems. Meanwhile, industrial processes very often involve sintering of multi-phase systems, and this problem deserves much more attention that it has done up to now. So I think that perhaps it would be useful to consider in more detail, during one of our next meetings, the problem of reaction sintering.

V. Mikijelj: Dr. Exner spoke about establishing a catalogue of problems important for industry. Meanwhile we know that problems in industrial practice are not the same in the different countries, and because of that it is more difficult for the people from industry in different countries to find a common language, than it is for the research people. For example there are not the same problems in metal powder industry in India and other developing countries compared with highly developed ones. Let us remember the problem of different quality of metal powders, that they have in India every day according to Prof. Tendolkar. It is difficult to believe that the problems of US industry are similar, especially in the case of large scale production with always very similar homogenous powders with particles having size distribution and shape nearly approaching to model requirements as it is the case for example.with the powders that Dr. Greshkovich used for his experiments. Because of that I could say to Prof. Coble yesterday that more complicated models are nearly approaching the behaviour or real materials in special cases that we start to meet in the contemporary industry in developed countries. This may explain why work considering sintering on models is evidently most intense in US, where real industrial powders can be nearest to models.

K.E. Easterling: We have heard about the large gap in powder metallurgy between industry and research. Unfortunately there is also as large a gap between the experimental research workers in this field and the theoretical physicists. In the case of sintering theory, Prof. Samsonov and his coworkers are making interesting qualitative use of the electron theory of solids in an attempt to make predictions in such practical applications as the sintering of alloy powders. On the other hand we - the experimentalists - are still waiting for even an approximate quantitative model of the surface energy of pure metals.

C. Greskovich: Although industrial processes are often very complex and difficult to control, there are several examples where a theoretical understanding in the development of ceramics has been succesfully transformed into production on a large scale. Two of such examples are Lucalox (MgO - doped Al_2O_3) and Yttralox (ThO_2 - doped Y_2O_3) which have excellent optical properties. These examples clearly demonstrate the need for a theoretical as well as a technological understanding of the entire sintering and grain growth phenomena.

L. Žagar (Chairman's summary): In his introductory report Prof. Thümmler has analyzed the present situation as far as the connection between theory and practice is concerned, and came to the conclusion that progress in the theory has been achived, but the practice goes still on an empirical way, because the existing theories can not be used in fabricating technical products. He made some proposals and recommendations how this state of matters could be changed.

In the following discussion 26 participants made comments and statements. It has been stressed that many useful ideas, as for instance the idea of activated sintering, were born in the practice and are now object of theoretical considerations.

But in some cases - as was pointed out by many participants - the application of a theoretical approach in practice was a success. The models were a good guide in fabrication of special products. Still more, starting from phenomenological observations formulas have been found, which were very useful in the past.

The practice of the sintering is not always interested in densification only but in properties of sintered products. We have a lot to do in these direction. It was criticized, that no papers have been presented dealing with the problems concerning the powders and their characterization. The chemical composition, the impurities, the particle size, and size distribution, the inner and outer specific surface, the particle shape, the surface roughness, its activity - all this is of great importance. In most cases there is not a questions of porosity, very large necks between particles are of the main importance. The sintering in practice is hardly a isothermal process. So models as e.g. the model of Johnson can be used. Statistical methods of analysis are to be introduced. A very important problem for the future is the study of diffusion processes in alloys.

In this respect some participants put detailed problems to the discussion which are important in their particulare environment. We heard about the problem of sintering of MgO from usual sources and about difficulties with dolomite and its use in metallurgy. Such questions show that sintering is related to quite different branches of industrial practice. Going back to basic science it was pointed out that more importance should be given to the study of surface energy of solid materials. Till now the study of diffusion processes was predominant. On the other hand it was mentioned that surface energy does not change in large scale as diffusion data do. The question was put, what does the practice want generally. The engineers have to formulate clear questions and open the problems without restrictions. But the scientists have to take account of the fact, that every industry has to struggle with competition.

A catalogue of questions and problems should be put down by the industrial people to learn know what they want to be done and make a priority list. This might be not easy, because different countries have different technical problems and even in same country there are different raw materials and different market requests.

Does the connection between scientists and engineers have to be intensified at least to some extent? There is the important question that the scientists and on the other hand the technologists and engineers do not speak the same technical language. This is matter of fact in many cases. One possibility to overcome this difficulty is to create common working teams, where the engineers join the scientists or vice versa. In industrial research and development today the opinion prevails that the best (i.e. the most "scientific" men have to be put in research. But his is not always the best decision and sometimes the opposite would be better.

The universities themselves have demonstrated till now little effort to translate and to interpret their scientific results and findings to industry, which perhaps could use these results to improve the products or production processes or make some innovation.

Summarizing the Chairman made the following statement.

In many countries the public opinion is with increasing intensity appealing to the scientists to get aware of their social task in their professional work. The goal of scientific work should not be only private satisfaction.. They should consider how the results and findings can be used in practice in order to make life easier for their own people and for all mankind. As a matter of fact there are in the world not only technological gaps but gaps as well between scientists and engineers, between universities and industry laboratories.

As we have seen, the field of sintering is a typical example of a gap between theory and practice, at least to a considerable extent. So one of the tasks of our ITS should be to make efforts in closing this gap and encourage the closer cooperation between scientists and engineers.