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THE PROBLEMS OF ADOPTING CONSTRUCTIONS AND THEIR PRODUCTION [1]

by

Lajos Bálint
Director
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SUMMARY

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In a developing country production based on product licence from developed country means considerable constructional and technological adaptational work. The reasons for this are: the construction produced by developed transferring industry is based on greater serial production, higher quality preformed products, more scientific professional knowledge, more advanced production tools and organization than that of the receiving country. This means that when applying licence constructional conceptions representing generally higher technical standard have to be replaced by more simple structures which perform functional work and which were also contained in licence. These can be realized by available means and technical knowledge yet assuring qualitative stipulations.

In order to provide required structional quality by means of more simple construction and less advanced production, technological principles and adaptable processes have to be applied properly and consistently in modifications performed at the adaptation of construction and production, as well. The study is devoted to deal with this problem without substituting technological trade books.

Major subjects discussed in the study are,

- Criteriums of construction soundness which are to be enforced at any technical level are: formulation and requirements of form and technological soundness.

- In the adaptation of constructions general technical attitude required by technology: careful examination and analisys not only of structural operation, but of manufacturing when designing.

- Assertion of technological soundness in the adaptation of component structures; technological and economical examinations which have to be performed in the original and adaptational designing and in selection of material when determining shape, dimensions, tolerances and surface finish.

- Selection of assembling method and assembling dimensional chain conception in the adaptation of construction: criterium for selection of complete, limited or partial changeability taking into account structural conception, nature of manufacturing and technological level. Which dimensional chain conception is desirable or required to replace with, if there are lower grade technological requirements instead of higher ones.

The subject associated with the effect of production specialisation and concentration on possible technical level in adaptation is less detailed here because it is discussed by the writer in a different study entitled, "Complexity, Specialisation and Concentration of the Engineering Technology".

When writing the brief study the writer took into consideration that the reader had needed technological knowledge or the reader can find it in respective technical literature.

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1. The standard of home technology and those embodying the product forming the subject of the licence

In such a country, in which the industry is still only developing, a problem is caused by putting into manufacture, with the aid of a licence of such a product, the documentation of which originates from a developed industry, and also represents its technical standard. The higher the technical standard of a structure and the technology embodied in it, the greater the difference which must be bridged in the course of its adoption.

The chief causes of the technical differences:

- constructions designed in developed industrial countries, belong to products manufactured in mass production, but in every case in larger series, in comparison with the industry of the adopting country,
- in general the accepted documentation is compiled on such kinds and qualities of materials and semi-finished products, which are either not obtainable or else with difficulty and rarely in the country adopting the construction;
- arising from the size of series, but also on the other hand as the result of more developed industrialisation, usually the manufacturing technology of the offered con-

struction requires more advanced machines, equipments, processes and tooling than the accepting industry has at its disposal;

- the acception documentation has been prepared taking into consideration a higher scientific and professional knowledge, than that which can be found at the moment in the place of acceptance;
- the documentation of the licence involves a higher form of organisation than that which can be assured at the place of adoption.

It is obvious however, that the products manufactured at the place of adoption must meet their functionary requirements, and the characteristic specifications - even if on a lower limit of tolerance - must be fulfilled.

This condition means that in the developing country at the time of receipt of the licence such a technical and organising activity is necessary, which is the particular problem of the adoption of construction and manufacture, if the general technical standard of the receiving place is lower than that of the place handing over the licence. However the solution of the question is not hopeless, the possibilities are attainable if experts both in technical and economic field are in possession of the necessary knowledge and apply it properly.

Although the question is that at the time of adoption the product and production must be degraded to a somewhat lower level owing to the given objective circumstances, even so this task requires a fundamental technical knowledge and demanding careful work.

It can be stated, that in possession of the designing, but mainly the technological fundamentals and by their consequent application, with knowledge of local surroundings and possibilities and adequate practical experience the adoption of the documentation can be successful, and later this will enable the technical standard to rise gradually.

Essentially the task is that:

- constructional solutions representing higher technical levels must be substituted by simpler structures fulfilling functionary tasks, which can be carried out in the given circumstances of production;
- in place of technology representing a higher technical level a ready to use technology should be applied assuring just sufficient qualitative conditions and for which the machines and equipments are at disposal and which can be still carried out relatively economically in local circumstances.

As in the developing countries in the constituents of the cost of production the wage quote, but greater part of over-head charges are also relatively less than in the developed industrial countries, in the case of lower productivity, too the production can be economical. The quality of the products in many cases can be realised instead of with accurate machines, with work requiring diligent, circumspect lengthy manual activity on simpler, all-purpose machines.

Just as the qualitativeness is not given by the machine, but in a large measure depends on the work of the worker, other technological rules, processes must be assured. Below an effort is made to show not economic but rather such technological tasks.

2. <u>The criteria, to be fulfilled at whatever technical level, of correctness of construction</u>

At the time of the designing of the constructions and also at their adoption structural operational demands must be assured, but notice must be taken of the forms and also of the economic productibility. Thus the construction is good if it satisfies:

a/ structural correctness,

b/ correctness of form, and

c/ technological correctness.

The structurally correct construction is well suited to operational demands: its kinematic system is simple and assures the required movements of the operational task; the dimensions and materials of the components safely suit the cross-section required by the given loading; a structure built from elements operates with safety; the prescribed demands of accuracy, the physical properties of the roughness of the surface layer of the component correspond to the motion-geometrical, the fitting, the frictional and life durational conditions, the power factors and/or efficiency of the product are suitable; the specific weight of the product is relatively small, etc.

The correctness of form requires that the product and the shape of its components satisfy the up-to-date form demands. The shapes should be pleasing to the eye, tasteful, proportional in dimensions. It is required e.g. of consumers' goods that they be stylish, and fit in harmoniously with the surroundings and furniture. e.g. from vehicles that they be streamlined, and their fittings comfortable. On the other hand very often the design slips through to the constrained fashionable shapes and colours. Only the forms which are moderate, of a cultured artistic taste, satisfying consumer requirements and economic demands are correct.

The technologically correct construction satisfies, beyond structural and formation correctness, also the demand that it can be produced by the most suitable processes in the least possible time and at the least cost; the structure and design solutions are adjusted to the requirements of productibility. This generally means the further perfecting of the designing because frequently the optimum solution must be found within the contradictory designing and technological demands. As the economical circumstances of the manufacture depends on the character of the production /on serial size, mass/ and as the method of production reacts on the construction, the technologically correct solution of the construction will also vary according to the production being single, serial or mass. In these there are different kinds of working methods, machines and equipments, thus the billets or semifinished pieces, the development of the shapes of the components, the dimensions even the prescribed accuracies can be different. Thus the technological correctness of the construction depends on the number of pieces to be produced.

It is obvious, that the standard of the state of development of the products, working implements and professional knowledge and working methods are historical categories, and at the beginning of industrialization were more primitive, then gradually developed. The handing over and accepting of licences accelerated the development, shortened certain phases of development, but it cannot entirely span the backwardness in standard any way. Consequently on the different technical standards the criteria of structural, form and technological correctness are different. The determined optimum of these belongs to the given standard, the attaining and realising of which is the actual aim at the time of adopting the documentation given on the basis of the licence. The attainable optimum can be higher the greater the mass of production and the higher the standard of the mental capacity at disposal, which participates in the adoption of the given production.

It is clear, that in the developing industry instead of automatic machine lines, one-purpose special equipment, expensive tools, mostly still all-purpose machines and implements are at its disposal, and the surface finishing, the shape and the designs of the construction must be modified in order to apply all-purpose methods, but at the same time satisfying the structurally, formationally and technologically correct criteria to be fixed on the given standard in the adapted construction.

3. General technical survey required by the technology while adopting the constructions

Just as on a given technical standard and in possession of the equipments in production the method of work cannot be chosen at will, at the time of the adoption of the construction obtained on the basis of licence the designer cannot be exempted from the necessity of examining the possible ways of production. The work of adapting designing must be examined not only from the operational point of view the appropriate shape and dimensions, but must strive for supplying these from the production point of view too. Even this is not sufficient, if one is convinced that the shapes designed can be realised with the required accuracy by any method of work, but in mind must follow right up those processes with which the components can be produced and assembled in the workshop. The components must not be examined only as mechanical elements, but in the imagination must be seen as the workpieces emerging from each other, from the raw material to the supply of the finished form and dimensions. In the knowledge of these, the structural solutions should be so altered that the most economical method of work will be applicable. It is expedient if at the time of designing more complicated components and structures the designer confers with the operation-designer.

This survey also means that the designer must refer several times in his structural drawings to the technological solutions, it must be indicated as on the basis of what kind of productive conceptions the designs originated, possibly instructions should be given regarding the manufacture.

Such prescriptions could already be on the original drawings, too; these probably would have to be re-marked according to the technology to be realised locally. E.g. on the drawings of machines beside the geometrical data of the microroughness, he should also give the direction of groove /and shape/, or determines the method of processing too.

Obviously, the technological prescriptions of the designer can be many sided, chiefly in the case of welded structures, articulated large workpieces, heat treated components, complicated, or pieces of a very strict tolerance, or structures with precise operating demands.

The designer can only satisfy all these, if beyond a common knowledge of designing, he knows the manufacturing technology thoroughly and acquires a technological attitude and way of thinking. Technological facts can be studied in university, further developed by diligent self-education and in the course of factory experiences, on the other hand technological attitude and way of thinking depend on the aptitude, ability, capacity for self-adaptation, will of the individual. Many years of experience can give a suitable routine. On the acquring of all these too, the technological correctness can only be valid if the designer consistently examines his structural solutions and with an unswerving will makes efforts for the combined satisfaction of the conditions for operating, technological and forming correctness. These conditions are dependent on each other, but at the same time they are of equal value and of the same significance, too.

4. The consideration of the technological correctness while adopting of component constructions for home industry

Although technological correct design is a task requiring complex and meticulous work, yet the main points of the realisation of the technological correctness can be put into a system, the tasks can be listed almost taxatively. The issuing of the solutions is not as simple, but can be found in more or less summarised forms in literature.

At the time of both the original and the adapting designs technological and economical examinations of the designs of machine components must be carried out in every task:

a/ at choice of material,

b/ at designing of shape or form,

c/ at supply of dimensions,

d/ at establishment of accuracy specifications,

e/ at determination of surface quality.

Generally the topics and line of facts of the tests to be carried out at the time of the solution of these designing tasks are as follows:

ad a/ To be examined at choice of material

a_1 - technological requirements and possibilities:

- workability of the material /ductility, machinability, ways and possibilities of heattreating, filling capacity in liquid state etc./;
- The change of properties of the material during processing /varying of strength, hardness, fibre-direction, occurring stresses etc./;
- The most suitable process for the working of the material, and for assuring the required material properties /pre-, intermediate- and post-treatment/;
- The unanimous determination of material characteristics taking into consideration the working process /on parts list: the name of material, quality, raw state, standard or catalogue reference, heat or other treatments/;

a_2 - economical requirements:

- Saving of material /small allowance prefabrication, material saving processing: deep-drawing, cold extrusion butt welding and surfacing etc./;
- Saving of time and cost /usually as above/;
- Exploitation of capacity /transfer of operations from the narrow of the production flow section/.

ad b/ To be examined at the time of designing of forms:

b_1 - technological requirements and possibilities:

- Simple configurations /as few as possible basic figures with plain surfaces for connecting each other/;
- Shapes which can be realised simply with few operations, all-purpose implements, few and small surfaces to be cut, easy approximation by prefabrication - e.g. casting, and forging etc./;
- The capacity of the chosen working to give exact shape /cavity filling capacity, wall thicknesses, etc./;
- The course of realising certain surfaces /shapes/ /how the shapes of the workpieces arise out of each other in the sequence of the processes/;
- The most suitable shape designing conforming to the working method to be chosen /forms, planes of split, its shape, a simple form; at cutting: simple tool, jig, machine setting, suitable clearance space etc./;
- Assurance of retentivity /effect of residual stress, examination of faults in shape caused by heat treatment and working/;

b_2 - economical requirements:

- Saving of material /thrifty shape development: decrease of waste, realisability of waste, shape which can be made by operation requiring less raw material: deep-drawn, welded etc./;

- Saving of time and cost /tipifying, standardisation, few and small surfaces to be machined, working in pairs or groups etc./;
- Exploitation of capacity; shape designing not burdening the narrow section of production flow.

ad c/ To be examined on supply of dimensions

c_1 - technological requirements and possibilities:

- The extent of the component /the collation of these on the tool machines and other equipments with dimensions to be worked; the control of the measurements from the point of view of loads and rigidity during the processing/;
- The supply of the dimensional chain /unanimity of the structural basis surfaces, collation of the structural and technological bases, supply of dimensions in measuring sequence, examination of the co-ordinated and chain-like dimensioning, the correct references to dimensions of symmetrical and circular pieces, clear survey of dimensions: grouping of dimensions according to operation and clamping, correct connection of dimensional chains etc./;

c_2 - economical requirements:

- Decrease of shoddies /uniform and unanimous dimension supply, coincidence of structural and technological bases/;

- Saving of time and cost /if the structural and technological dimension network coincide there is no need for conversion; the measuring should be simple and natural/.

ad d/ To be examined at accuracy specifications

d_1 - technological requirements and possibilities:

- Unanimity of tolerances /collation of standards and correct determination of suitable signs of home standards; the collation and supply not only of dimensions, but of shape and position tolerances; supply of specifications refering to non-toleranced dimensions and shapes/;
- Examination of adherence to tolerance /faults occuring from the previous working and the recognition of the faults of the operation next in turn, summing them up taking into consideration their character - in scalar form or according to the law of probability - ; consideration of working method assuring tolerance/;
- Assurance of maintaining accuracy of dimension and shape /suitable rigidity, stress decreasing heat-treatments in due time, and identical machine, tool, device, worker and inspector etc. for production of a serial workpiece/.

d_2 - economical requirements:

- Reduction of shoddies, saving of time and cost /the tolerances should not be stricter than the accuracy required by the operation; the dimensional chains should be the shortest possible; least possible working on non-fitting parts, examination of the economy of instrumentation and tooling etc./.

ad e/ To be examined at determination of surface quality

e_1 - technological requirements and possibilities:

- Collation of the roughness with tolerance of dimensions /that is the establishment and specification of tolerance and working corresponding to the roughness/;
- The unanimous specification of roughness /with such standard data, which can be established in the factory/;
- The examination of the adherence to roughness /establishment of the lapping and refining capability of the material, examination of the vibration conditions, determination of suitable tool geometrical and technological data/;
- Examination of the physical properties of the processed surface /from the point of view of abbrasion resistance, corrosion resistance, dynamic loading etc./.

e_2 - economical requirements:

- Decrease of shoddies, saving of time and cost /specification of largest roughness, which still corresponds to the operational and endurance requirements/;

The answer /and thus the solution/ to the greater part of the questions examined and listed above, with a general technological knowledge, can be found on the basis of literary data at public disposal. However there are problems concerning the judgement of technological correctness for which such calculating processes, judging points, practical directions and date are necessary, which are not yet in literature, or can only be found with great difficulty. It belongs to the future task of research and literature to work out such aids and directions, with which the realisation of technological and economical correctness can become operative work. Further on efforts will be made to give a few points on these.

<u>The establishment of the economic working method</u> is possible by an analysis of time and cost. An examination of cost of production is also necessary in order to establish the economical tool machine, the economy of tooling and instrumentation.

<u>Realisation of work and time studies.</u> The time functions - regular coherent monograms and diagrams of allocated time and reference basis - give a possibility to establish from among the one or more possible operations or technological processes, the one requiring the shortest time in the given circumstances /1/. These are valuable aids not only in the hands of those preparing norms and technologies but for the designers, too.

<u>The establishment of cost of production of component</u> for the economic tests can be satisfactory as follows

$$C = \left(C_r - C_u\right) + \sum_{i=1}^{n} \left[c_{pi} \frac{t_{pi}}{n} + \left(c_{di} + c_{mi}\right) \cdot t_{di} + c_{ji} \frac{P_{ji}}{n_y} + c_{ti} \frac{P_{ti}}{n_l} \right]$$

where: n is the number of operations, C_r the cost of brutto raw material, C_u cost of used waste, c_{pi} cost of preparation per minute, c_{di} cost of piece per minute, c_{mi} cost of machine per minute, c_{ji} and c_{ti} factors of cost refering to jig, attachemen or special tool, t_{pi} and t_{di} the preparation time and minimum time of piece, P_j and P_t price of j i g and tool, n_y number of pieces produced per year, n_l number of workpieces which can be produced during whole life duration of the tool.

In the above expression

$$c_p = m \left(1 + \frac{R_i}{100}\right); \qquad c_d = m \left(1 + \frac{R_i + R_a}{100}\right);$$

$$c_j = \left(\frac{1}{a_j} + \frac{R_k}{100}\right); \qquad c_t = \left(1 + \frac{R_t}{100}\right)$$

where m is minute wages in monetary unit, R_i and R_a are the periodic and proportional over-head costs in percent of the working wage; R_m, R_j, R_t additional costs of the machine, the jig, the tool /repairing, maintenance etc./ in percentage of their prices; P_j price of j i g ; H_y hours of production-time of machine annually; a_m and a_e amortisation time of machine and jig /year/.

Calculation according to the above-mentioned expressions only appears complicated at sight. However, for its utilisation it is necessary that the factory bookkeeping should establish the cost per minute according to each machine, and the c_j and c_t factors according to kind of jig, attachments and tool and degree of complication. The value of H_y and n_y can easily be given by the Programming office. It should be noted that the developing of the factory bookkeeping to such a level is of economic interest, without this neither the economical plant management, nor the economical technology can be realised.

<u>The selection of the economical working process /and tool machine/</u> is possible by the comparison of cost of production of several working methods. The points of intersection of the

Fig.1. parabola branches which illustrate these /Fig.1./ determine the critical number of pieces - size of series - at which one or other process becomes economical.

The critical number of pieces determined by two processes /1/:

$$n_c = \frac{c_{p2} \cdot t_{p2} - c_{p1} \cdot t_{p1}}{\left(c_{d1}+c_{m1}\right) t_{d1} - \left(c_{d2}+c_{m2}\right) t_{d2} + \frac{c_j}{n_y}\left(P_{j1}-P_{j2}\right) + c_t\left(\frac{P_{t1}}{n_{t1}} - \frac{P_{t2}}{n_{t2}}\right)}$$

where the meaning of the marks are identical as before.

If a rougher value is suitable, the critical number of pieces can also be calculated from the allocated time:

$$n_c = \frac{t_{p2} - t_{p1}}{t_{d1} - t_{d2}}$$

Thus in the case of a given serial size the method of work to be applied can be established and this can be taken into consideration at the designing of the component.

The economical analysis of the use of jigs /1/. If the designer has to decide while designing the component as to whether to choose a shape which needs attachments or jigs or one which does not, the economy of the use of instrumentation or jigging is decided, if the saving of cost of production reached with it is greater than the quota of its cost falling to one workpiece, or that is

$$c_p \cdot \left(\frac{t_{p1} - t_{p2}}{n} \right) + \left(c_d + c_m \right) \cdot \left(t_{d1} - t_{d2} \right) \gtreqless c_j \cdot \frac{P_j}{n_y}$$

where the markings are identical with the previous ones, index 1 refer to values of operations without attachments or jigs, index 2 to those with them.

If costs per minute are unknown, it can be calculated roughly thus:

$$m \cdot \left(t_{d1} - t_{d2} + \frac{t_{p1} - t_{p2}}{n} \right) \cdot \left(1 + \frac{R}{100} \right) \gtreqless \left(0{,}5 + 0{,}6 \right) \cdot \frac{P_j}{n_y}$$

The economy of the use of a special tool can be examined in a similar way to the above, that is:

$$c_p \cdot \left(\frac{t_{p1} - t_{p2}}{n} \right) + \left(c_d + c_m \right) \cdot \left(t_{d1} - t_{d2} \right) \gtreqless \frac{P_t}{n_t}$$

or if the minute cost is unknown, roughly with the following:

$$m \cdot \left(t_{d1} - t_{d2} + \frac{t_{p1} - t_{p2}}{n} \right) \left(1 + \frac{R}{100} \right) \geq \frac{P_t}{n_t}$$

The use of tipified operation or production plans. The collection of tipified operation or production plans prepared for the characteristic machine components is useful for the designer, if he wishes to become acquainted with the working process of a component listed in the collection or of a similar one, in production or make /accuracy, roughness etc./ of different characters. These contribute to the unification of the technology of similar pieces, the unification of the jigs, attachments, fixtures and tools, the reconcilement of the conceptions formed by designer and technologist concerning the product, and the technological training of designers. The tipified operation and/or production plans beyond the sequence and description of the operation, name the most suitable machine tools, indicate the technological basis and dimensions, give the method for clamping workpieces, the tools, and give directions for the principle solution of the jigs, fixtures etc. to be used. The tipified operation or production plans can be found in the literature /1/, /2/, /4/, /5/, /8/ can be completed with the tipified operation plans collected in the factory or by national organisations.

Collection of examples for giving technologically correct shape can be prepared for components produced in different ways, casting, forging, pressing, welding, cutting etc./.

From these the designers see the "correct" and the "incorrect" solutions. The examples collected from the literature /1/, /2/, /3/, /5/, /7/, /8/ etc./ can be complemented to correspond with local tasks, and to give motive and expedient short verbal explanation to the examples.

Points of view on selection of basis. On principle the dimensioning is technologically and serviceably correct, if the structural and technological bases coincide, or that is during working the dimensions are measured from the same surface starting from which the designer also measured them /then there is no fault in choice of basis/. This principle should also be followed if on the adoption of the construction structural modifications are necessary. If on the other hand the designer is not certain of the method of working he should without fail consult the operation or production designer. If the technological basis cannot be determined previously, the designer should stick to the measurements given from the designing base /from the point of view of its operation from the most characteristic surface/ because only thus can a clear picture be obtained of the role and importance of certain dimensions and tolerances.

General regulations: a/ if the coordinate dimensions are given on the drawing, the structural base /base of dimension supply/ should by all means be that, from which the dimensions are measured at time of processing /measuring base/; b/ in the case of chain dimensions, the structural /dimension supplying/ base should be the surface to which the position of the surface to be processed is most strictly tolerant; c/ the structural base should be the measuring have /unvariable criteria of the bases/ in as many operations as possible; d/ the number of members of the dimensional chain should be the smallest possible /shortest way principle/; e/ accuracy of position /parallelism, perpendicularity, etc./ during of specification the structural /dimension supplying/ base should be that in proportion to which the relative position with the specified tolerance must be kept; f/ at the time of the supply of dimensions attention must also be paid as to how the workpiece will be clamped on the tool machine: the laying surface base should be the more extensive surface of the piece; g/ if there is not a suitable laying surface base, provision should be made for auxiliary bases and for the rigidity of the workpiece /1/, /2/, /5/, /8/.

Taking into consideration the clamping of the workpiece on the tooling machine and the faults in selection of base.

It is known, that if the structural and technological bases do not coincide, then the dimensions acting as collective members in the structural dimensional chain present themselves in the technological dimensional chain as resultant /closure/ members and thus their scattering is greater than that of the specified tolerance. Owing to this at time of designing position determination of piece on the tooling machine must be considered and determined according to rules of the dimensional chains, how large the faults in the choice of base are likely to be /the scattering of base dimensions/.

It must be inspected as to whether the component can be produced at all according to the applied dimensions or whether the deriving faults still correspond to the operating conditions of the component. Owing to the neglection of the dimensional chain calculations in many cases the designers give dimensions on the drawing which in themselves cause shoddies. For the facilitation of the calculations such a collection of examples can be prepared, in which for the classical cases the position determining fault is given for the case of the different kinds of clamping of the piece /1/. In these the designer finds that dimensioning system, which corresponds to the practical clamping of the piece, or on the basis of examples in the case of given dimensions can refer on the drawing to the positional determination on the basis of which the specified tolerance can be observed.

It is indispensable to analyse the tolerances and dimensional chains of complicated, multi-dimensional components, and thus the calculation of faults in base choice; in case of necessity the cooperation of the operation or production designer should be asked.

<u>The coordination of the dimensional tolerance and the roughness; the accuracy to dimension and roughness can be economically ascertained</u> /1/. During the course of realisation of the technologically correct designing, among other things, the designer must receive answers to three questions:

a/ establishing the dimensional tolerance on the basis of the operating conditions what is the largest possible roughness he should coordinate to it;

b/ establishing the roughness on the basis of the operating conditions what is the dimensional accuracy /tolerance/ he should fix;

c/ with what kind of processing can the determined dimensional accuracy and roughness be realised on the surface of given shape and dimension, or what dimension accuracy and roughness can be realised at all with certain processing.

The designer rarely or only sparsely finds references to these questions in literature: in summarised form I have tried to give a solution to these in my book /1/.

Taking that according to Moll, safely, $R_{max} = 0,25\ T$ and according to Djacsenko $h_q = 0,18\ R_{max}^{1,1}$; as well as on the that in cutting $R_a \approx h_q$, expressing the relationship between the D /mm/ diameter to be processed, IT tolerance quality and

Fig.2. R_a /μm/ average roughness the diagram No.2. can be plotted. From this can be concluded what is the largest roughness with which the specified tolerance quality can be realised for a given diameter, and what is the largest tolerance quality cutting processing with which it is possible to produce the specified roughness on any diameter.

The tolerance quality and roughness may be assured by certain processing as given in Tables 1., 2. and 3. /on the

Tables 1.,2.,3.

basis of documentary and experimental data/.

If it is necessary to modify the documentations of licence while adopting, then with the aid of the diagram and the tables the conjugated tolerance quality, roughness and processing method to be used in the receiving industry can be determined.

The control of possibilities for the adherence to tolerances /1/. If such tolerances are to be realised, which are smaller than the accuracy of the economic processing /falling beyond the strict bounds of the above-mentioned tables/ then the probability of the adherence of these must be controlled already at the time of designing.

The general expression of resultant errors of cutting processing carried out in one clamping is given below

$$\delta_{resultant} = \delta_r + \delta_{fm} + \delta_{mg} + k \cdot \sqrt{\delta_v^2 + \delta_{me}^2 + \delta_b^2 + \delta_c^2}$$

where δ_r the regular errors of the machine, tool and attachment independent of loading, δ_{fm} errors of setting of machine, tool, attachment, δ_{mg} subjective error made by control with gauges, δ_v varying /forming/ errors independent from loading /elastic and heat treatment deformations, caused through wear of tool, or by stress/, δ_{me} errors of measuring instruments or methods, δ_b errors of base selecting, δ_c error in clamping of workpiece, k errors depending on factor of scatter /for cutting $\approx$ 2/.

For strict tolerating work /e.g. for fine turning, fine grinding/ the values of certain members must be established separately by calculating /e.g. deflection, wear of tool, error of base selection etc./ by practical measuring /machine precision, attachment precision, error of instrument etc./ or from literary data. In order to be able to adhere to the T tolerance it is necessary that

$$T = \delta_{resultant}\ .$$

<u>The establishment of the measurement of blank or billets.</u>

The dimensions of blank or billets, castings, forged pieces etc. are frequently different in the home production than in the licence documentation; then they can only be established by the correct calculation of allocations; the allocations on the other hand can be calculated on the basis of the errors occuring during the course of processing.

The allocation of any operation:

$$Z_{op} = \vartheta_{s_l} + k \cdot \sqrt{\vartheta_{pg}^2 + \vartheta_{pd}^2 + \delta_b^2 + \delta_c^2}$$

where ϑ_{sl} is the defective surface layer deriving from previous operation, ϑ_{pd} and ϑ_{pg} are the dimension and geometrical tolerance of previous operation, δ_b and δ_c are base choice and clamping error of operation next in turn.

The expression of complete allocation to be assured on unworked piece is /1/:

$$Z_{\Sigma} = \vartheta_n + k \cdot \sqrt{\vartheta_{ug}^2 + \vartheta_{ud}^2 + \delta_{nb}^2 + \delta_{nc}^2} + \sum_{i=2}^{m} \left(Z_{tabl} + \delta_{ib} + \delta_{ic} \right)$$

where: u index represents the unworked /rolled bars, forged pieces, castings, blanks, billets - without any working operation/ piece, n index roughing, i index after roughing process; Z_{tabl} the values given in table form in literature on allocation /1/, /4/, /5/, /8/. The defective surface layer of the ϑ_{uw} unworked pieces can be found as literary data /1/, /8/; ϑ_{us} and ϑ_{ud} are the standard values of the shape and dimension tolerance of the unworked piece; the δ_b can be counted as base selection errors, δ_c can be estimated.

The dimensions of the unworked piece can be obtained if the allocations /taking into consideration the direction of the processing/ are added to the dimensions of the finished component. The shrinkage of castings and forged pieces must be taken into account.

5. <u>The selection of the method of assembling and the solution of assembling dimensional chain at the time of the adaptation of the construction</u>

The dimensional chain solution means such a practical establishment of the tolerance /fitting/ of the dimensions that the assembling is carried out in one of the following ways, that is the parts are:

a/ either without hindrance /with completely changeability/,

b/ or with a definite probability /with a risk, limited or conditional changeability/,

c/ or by careful <u>selection</u> /selecting assembly with partial changeability/,

d/ or it can be assembled /by dimension corrections - with use of fitting elements/ on a previously marked out site.

The application of the four or five kinds of dimensional chain solutions is determined by primarily the mass character of production but chiefly the technical level of the parts production, too. In the mass production of developed industry it is the complete changeability which has prevailed and is the most economical too, or in the case of products consisting of a few parts /e.g. ball-bearing production/ the selecting assembling.

The lower level parts production, which is however, the concommitant of production in small series, enables an assembling method on a lower level, thus the complete changeability and the selecting assembling is substituted by the limited changeability and the adjusting and setting method.

At the time of the adaptation of the construction, if one has to switch from one method of assembling to another, the dimensional chain must be solved in a deviating method. This is made necessary possibly by the different build-up of the measurement network, but in any case by the change and recalculation of the joinings /tolerances/. The designer and technologist, in possession of the knowledge of the theory and the solving methods of the dimensional /and tolerance/ chains, can solve the tasks.

Here a few remarks must be made in connection with the solution of dimensional chains, although professional literature gives the necessary data.

Relinquishing complete changeability the tolerances can be enlarged and the component production becomes cheaper, and can be realised with simpler implements /machines, tools, measuring instruments/, but however, risks must be accounted for, perhaps certain pairs cannot be assembled, or perhaps at time of assembling measuring or post-adjusting operations are necessary. It can always be decided on the base of examination of the economical calculations and the local possibilities when and where to apply the complete changeability in the adapted construction, and where other dimensional chain or assembling methods.

<u>Complete changeability</u>, although enabling quick and certain assembling, owing to the narrow tolerances - and thus the costly production of components - is only economic in the case of large serial production, or of dimensional chains consisting of only a few high accuracy members, or of low accuracy multi-member ones.

<u>Limited changeability built on probable dimensions</u> is already suitable for the solution of the dimensional chain consisting of several members, because with relatively little risk of shoddy /e.g. 0,3 %/ there is a possibility of significantly widening the production tolerance of the component /perhaps twice as much/, and thus for such a cheapening of the component production which will cover many times the previously calculated shoddy.

<u>The method of selecting assembling</u> is very suitable for the solution of dimensional chains consisting of a few /e.g. 3-4/ members, if the permissible errors /tolerance/ of the closure can only be small. It is rarely applicable if the connecting dimensional chains have several common members. As the tolerances of the components can be increased several times, the production of parts is very cheap and therefore the selection is renumerative. It is expedient,

however, in the selecting method to prepare the clamping and clamped dimensions for identical tolerance quality.

<u>Method of post-fitting</u> is suitable chiefly in the small serial production. Its advantage is that the parts can be produced cheaply and the precision of the dimensional chain can be finally ascertained, too. This widely covers the disadvantage that the equalising /closure/ member has to be fitted in the assembling-work shop on the site, by post-working. The equalising member, however, must be carefully selected: it should be able to be fitted last into the dimensional chain /the assembling chain/, it should not be a connecting member to another dimensional chain.

<u>The setting /compensational/ method/</u> is identical to the post-fitting method, but the equalising member can be set, compiled from parts, thus it needs no remachining on the site. The neglection of the last-mentioned method is an almost incomprehensible phenomenon whereas in developing industry it is the most suitable in the largest area.

6. <u>The influence of the specialisation and concentration of production at the time of adaptation on the technical level to be realised</u>

The increase of the mass character, or serial size is one of the most significant factors, that the highest possible level of technique be adapted from the document obtained by licence at the time of adaptation. However, the small and medium serial production is characteristic of the industry of the developing countries, and large serial and mass production only rarely occur. The relative increase of the mass, however, can be reached, if above factory level - e.g. national, or regional - specialisation and concentration is realised in industry.

The specialised concentration on the technological basis of production and the realisation of grouped processing - owing to its influence on mass increase - enables the application of technological processes in large serial production in the component production, but perhaps also in the assembling, even then, too, if the products must be manufactured in a relatively small series.

Further details on these possibilities are contained in the study compiled by L. BALINT: "Complexity, Specialisation and Concentration of the Engineering Technology".

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Table 1.

Tolerance and Roughness on External Cylindrical Surfaces Possible to Machine Economically by Cutting

Machining		Tolerance IT	Roughness R_a /µm/	Dimension Limit mm
Turning	roughing	IT11	12,5	
	semi-finishing	IT10, IT11	3,2 -12,5	
	finishing	/IT8/, IT9	0,8 - 6,3	
	fine turning	/IT5/, IT6, IT7	0,2 - 1,6	
Grinding	roughing	IT10	0,8 - 3,2 /6,3/	
	finishing	/IT6/, IT7, IT8	0,2 - 1,6	
	fine grinding	IT5, IT6	0,1 - 0,4	
Honing		IT5, IT6	0,05- 0,5	
Lapping		IT5, IT6	0,01- 0,2	

Table 2.

Tolerance and Roughness on Cylindrical Inside Surfaces Possible to Machine Economically by Cutting

Machining		Tolerance IT	Roughness R_a /um/	Dimension Limit mm
Drilling / Boring	without fixture	IT13	≥6,3	d = 0,25 - 30
	- in jig	IT12	6,3 -12,5	
	reaming with twist drill	IT10, IT11	3,2-12,5	d < 80
Counterboring	roughing	IT12	6,3-50	with countersink d < 150
	finishing	IT10, IT11	3,2-12,5	with drilling block d < 450
Reaming	single-pass	IT8, IT9	0,8- 3,2	d < 30
	double-pass	IT7, IT 8	0,4- 1,6	
Broaching		/IT6/, IT7, IT8	0,1- 3,2	d < 80
Turning	roughing	IT12	12,5-50	d < 1000
	semi-finishing	IT11	6,3-25	
	finishing	IT9, IT10	1,6- 6,3	
	fine-turning	/IT6/, IT7, IT8	0,2- 1,6	d=6-100; l < 100
Grinding	finishing	IT8, IT9	0,2- 1,6	
	fine grinding	IT6, IT7		
Lapping		/IT5/, IT6	0,01-0,8	

when 0,5 ≦ l ≦ 3d ; if d is the diameter, l is the length of the hole.

Table 3.

Tolerance and Roughness on Plane Surfaces Possible to Machine

Economically by Cutting

Machining			Tolerance IT	Roughness R_a /µm/	Dimension Limit mm
Planing	roughing		IT12	12,5–50	
	finishing		IT9 – IT11	1,6–25	
	fine		IT7,– IT8	0,8–3,2	
Milling	with side milling cutter	roughing	IT11 – IT13	6,3–50	
		finishing	IT9, IT10	1,6–12,5	
	with face milling cutter	roughing	IT10 – IT12	3,2–50	
		finishing	IT8, IT9	1,6–12,5	
		fine –	IT7, IT8	0,8– 3,2	
Grinding	roughing		IT10 – IT12	1,6– 6,3	
	finishing		IT8, IT9	0,4– 1,6	
	fine grinding		IT6, IT7	0,2– 0,8	
Lapping			IT5, IT6	0,01–0,2	

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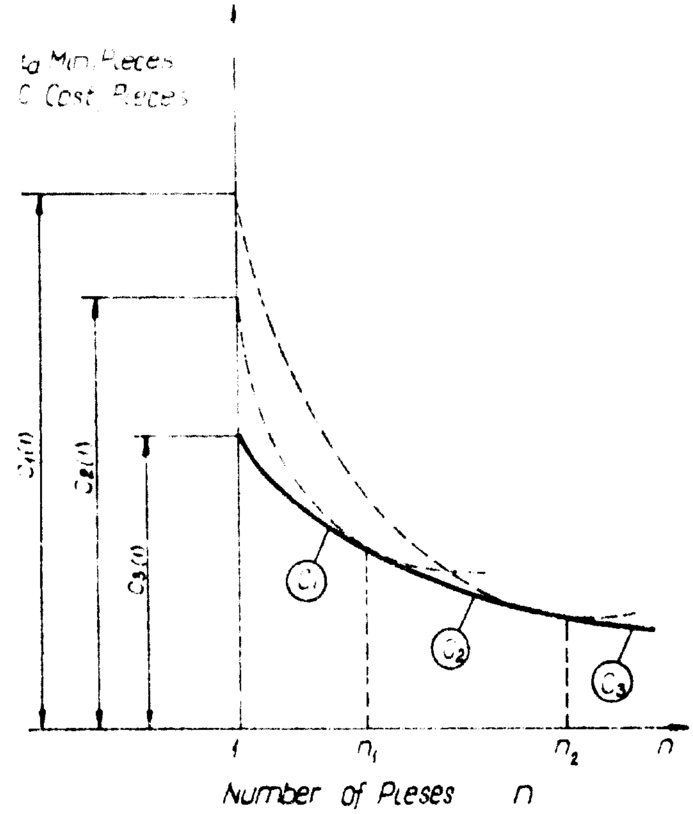
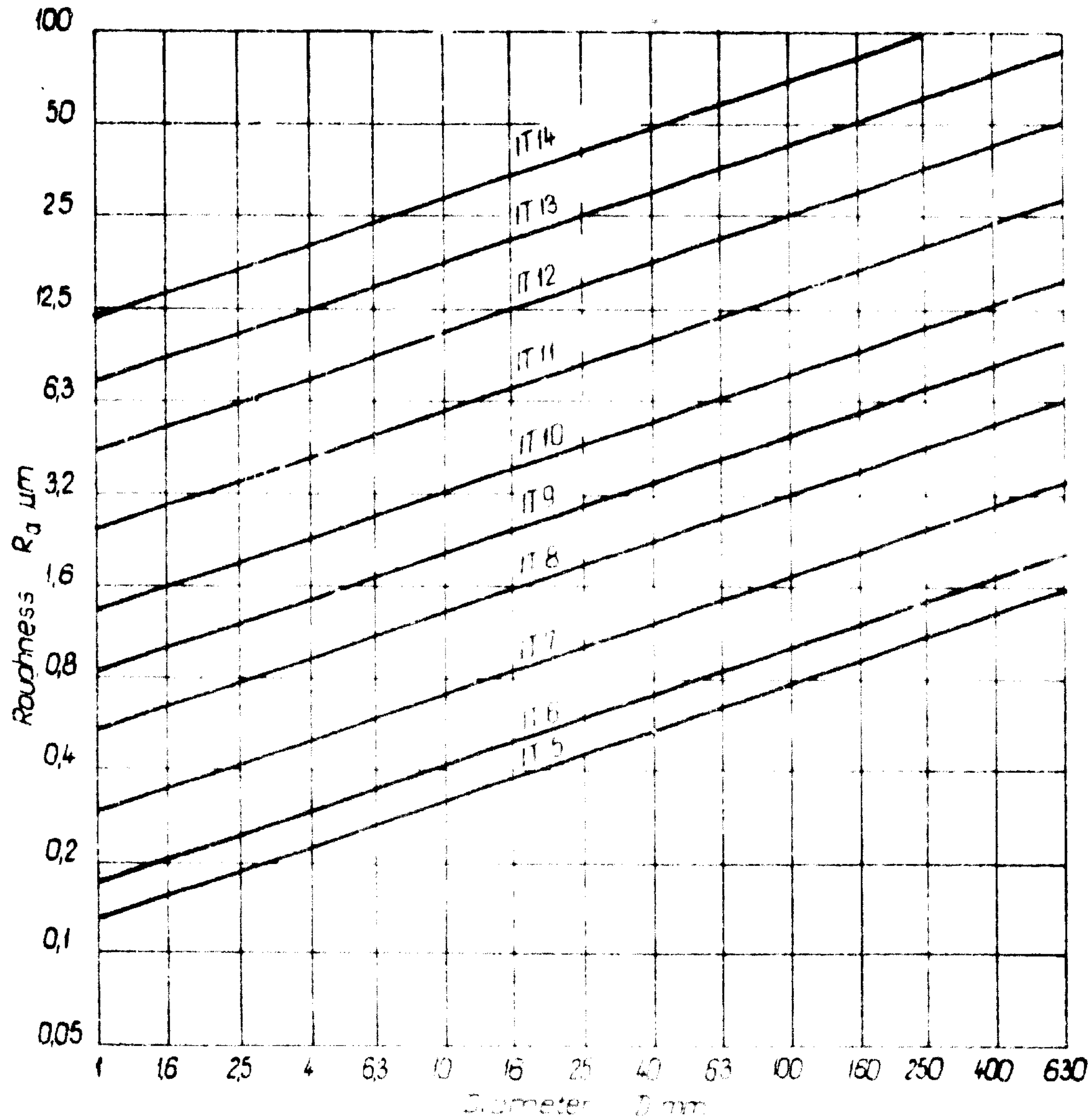

ta Min/Pieces
C Cost Pieces
C1(1)
C2(1)
C3(1)
C1
C2
C3
1
n1
n2
n
Number of Pieses n

Fig.1

Fig.2


100
50
25
12,5
6,3
3,2
1,6
0,8
0,4
0,2
0,1
0,05
Roughness Ra µm
IT14
IT13
IT12
IT11
IT10
IT9
IT8
IT7
IT6
IT5
1
1,6
2,5
4
6,3
10
16
25
40
63
100
160
250
400
630

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