**Dr. Eng. I. IOSEFIDE**
**Secretary for economic problems**
**Galaţi County Party Committee**

# The Increase of the Efficiency of Repair Activity for the Iron and Steel Equipment

*"Neither a machine nor an equipment below the planned efficiency, no un-worked minute"*

**Nicolae Ceauşescu**

**Report delivered at the all-country conference of the management staff of enterprises and industrial and construction centrals.**

## 1. INTRODUCTION

The ample programme for the development of the Romanian economy in the present five-year plan period and in the coming years, adopted by the Tenth Congress of the Romanian Communist Party and by the National Conference of July 1972, emphasize the necessity for a complete use of all production capacities through the continuous increase of the indices of the intensive and extensive exploitation of the machines and installations possessed by them.

The improvement of the activity of maintenance and repair of machinery and equipment is one of the main ways ensuring the best use of the production capacities and the increase of the general efficiency of the entreprises.

The sudden change, during the last few years, in the role and importance of the maintenance and repair activity was determined by the following factors:

a) the considerable increase of the value of the new installations purchased, due to their constructive and functional improvement;

b) the increase of the complexity of the installations by raising the level of mechanization and automation of processes and by using equipment specific of various technical branches;

c) the risks of a rapid technical and economic obsolescence because of the intense processes of physical and moral wear of the installations;

d) the ever bigger losses caused in the case of the damaging of the installations and their stationing in repair;

e) the continuous increase of the maintenance and repair expenses and their increased share in the cost price of the products.

A permanent increase of the expenses made, of the absolute number and of the share of the personnel employed in the maintenance and repair activity, is being registered on a world plane.

Although being an auxiliary activity, the maintenance and repair of the equipment have long ceased to be considered a secondary problem.

It is absolutely necessary to approach in a new way the sphere of the preoccupations and of the means used by this activity, so that in the period of the unfolding of the production processes, the installations will work at the best parameters, faultlessly.

From the ensemble of measures which can be taken in this direction, the programming, on a scientific basis, of repair work in view of replacing the elements before they become defective, is of particular importance.

The drawing up of the effective plan for the repair activity is a more difficult task than the programming of the basic production, as the conditionings are more numerous.

The other main aspects of the activity should not be neglected either: the organization of maintenance, the repair technologies, the overhaul equipment, etc. These aspects, however, are dwelt on, at length, in the literature of speciality, the efficient solutions whose application allows their adequate solving for the present stage, being also indicated.

As regards the programming of repair, the studies and some of the solutions recommended so far failed to find yet solutions which can be largely applicable for the enterprises or for some branches of production.

In keeping with the economic consequences of the stagnation of the machines and installations, as a result of their disrepair, a big variety of repair programmes can be adopted, beginning with that ensuring the maintenance of the equipment in an almost perfect condition, at the cost of frequent overhauls for the systematic replacement of the elements at fixed terms, regardless of their technical condition and, ending with the system envisaging the functioning of the installations to the limit of possibilities.

However, none of the possible variants for the repair of installations can be recommended as a generally valid solution for all enterprises and equipment used.

The establishment of the best repair programme is a rather complex problem of operational research in view of determining for each separate case the necessary equillibrium between the frequency of overhauls, the consumption of parts and the nonfunctioning period of the installations.

Consequently, the working out of such a programme requires a big volume of calculations which cannot be carried out by using the traditional means, in a period of time satisfactory for the needs of practice.

The utilization of electronic computers allows the considerable reduction of the volume and length of these works, thus creating the necessary premises for improving the repair activity.

## 2. CONSIDERATIONS ON THE BEHAVIOUR IN EXPLOITATION OF THE IRON AND STEEL EQUIPMENT

The extremely negative effects of breaks in production, the stationing of the machines and installations for repair caused the specialized staff to make, in the last few years, many studies on the causes producing the fault of the equipment, trying to systematize them and to establish the methods for improving the activity of exploitation and maintenance which should lead to raising the length of functioning of the installations, under the conditions of the obtaining of an adequate economic efficiency.

Such actions are highly efficient in the units of the iron and steel industry which, due to the increased value of the equipment used and of its high productivity, are registering considerable losses in the periods of non-functioning of the main installations.

The necessity of continuously raising the economic efficiency of production has imposed the completion of the classical concept about the quality of the equipment with the notions about reliability and the capacity of maintenability.

One of the indicators widely used for estimating reliability is the intensity of defects $\lambda(t)$. Its size is given by the relation of the number of defects produced in a certain time interval and the number of objects which were in a good functioning condition at the beginning of this interval.

$$\lambda(t) = \frac{\Delta n(t)}{N(t)\Delta t} \tag{1}$$

where:

$\Delta t$ is the considered time interval;
$\Delta n(t)$ — the number of defects produced in this interval;
$N(t)$ — the number of objects in a good functioning condition at the beginning of the interval $(t, t + \Delta t)$.

The fact that by a simple summing up of the ordinates of the characteristics $\lambda(t)$ of the elements, the characteristic $\Lambda(t)$ of the whole ensemble is obtained, is opening up large possibilities for studying the reliability of the defects, because only the aspect of the characteristic $\lambda$ allows to estimate the particularities of the defects and the methods for preventing them.

Figure 1 presents one of the typical characteristics.

In keeping with the intensity of the defects, three distinct periods can be noticed:

I. **The initial functioning period,** in which a considerable number of deteriorations are taking place. The weak, under-dimensioned elements with hidden defects, those assembled inadequately etc. deteriorate.

For the first period to be as short as possible, it is necessary that the running in of the installations with the producer should be carried out beforehand. In the case of the iron and steel equipment, this is more difficult because of the big size and the diversity of the elements.

In fact, these installations made up of numerous heterogenous elements do not require a special wearing beforehand, because the curves $\lambda(t)$ give on the initial portion a $\Lambda$ which has no pronounced maximum.

Upon the commissioning of the iron and steel installations some general wearings, of short duration, are usually carried out, the subensembles and component installations having previously been run in by the suppliers.

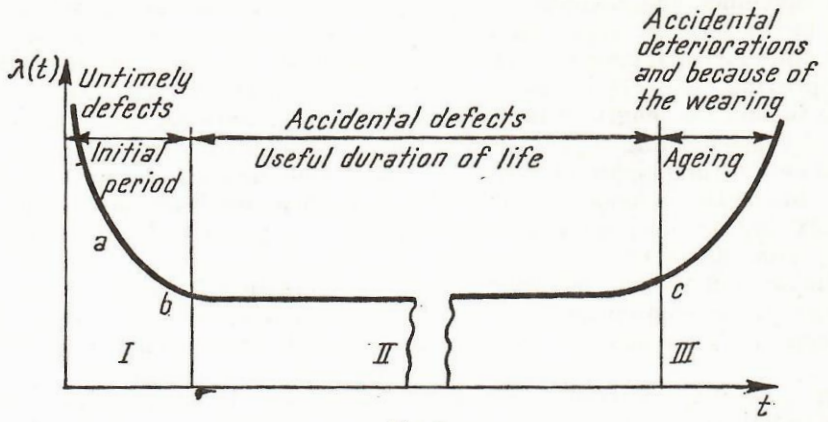


Fig. 1

II. **The main functioning period,** in which the intensify of the defects is the lowest.

III. **The final functioning period.** In this period, the intensity of the defects is growing because of the wearing of some of the elements at the maximum admissible level, the further exploitation of the system without their replacement becoming irrational.

Any continuous distributions of the theory of probabilities can be used as theoretical distributions of the period of faultless functioning.

The exponential distribution of the time of faultless functioning is typical of the complex systems made up of heterogeneous elements with different characteristics $\lambda(t)$. If in the exploitation of these elements no breakdowns are taking place caused by the wearing at the maximum admissible level, the intensity of the defects can be considered as constant.

The normal distribution of the time of faultless functioning is largely applicable to the mechanical and rather simple electric parts, with homogeneous destruction characteristics, carried out under the conditions of a stable unfolding of production.

Many experiments made in the last few years confirm the fact that when the probability of the defects changes in time, the Weibull distribution can be used with good results. This distribution is recommended to be used at the products where the phenomenon of fatigue is intensely occuring (electronic tubes, ball-bearings, mechanical parts, etc.) and at the aggregates and systems which are not provided with redundancy, such as is the case with the iron and steel equipment.

The probability density in the case of the Weibull distribution is given by the relation:

$$F(t) = \nu \cdot kt^{\nu-1} \cdot exp(-kt^{\nu}). \qquad (2)$$

Maintenance is the ensemble of upkeep, overhaul and repair activities which aim at removing the defects of some parts and subensembles and at reconditioning the entire installation.

On the basis of the knowing of the reliability of the equipment, of the component parts and subensembles respectively, the parameters of the repair system can be established scientifically, respectively the frequency of technical overhauls, the volume and duration of the necessary repair work.

The $\lambda$ curve shown in Fig. 1 states the necessary repair to be carried out for each period of time.

The measures for preventive replacement are justified only in the case of deterioration of the parts because of their wearing up to the maximum admissible limit.

The systematic recording of data illustrating the functioning of the machines and installations for a longer period of time and their interpretation by using the modern methods of statistical-mathematical analysis allows the confrontation of the adopted repair systems with the concrete requirements of exploitation.

The diagram of the total stoppages for repair of the thick sheet rolling mill in the first six years of functioning does not register accentuated tops of the defects, the evolution of the duration of interruptions showing a low fluctuation with every passing year.

A somewhat different evolution is marked by the expenses for the repair of the mechanical equipment (Fig. 2). They register a maximum value in the first months of functioning and substantially decrease in the following period. After three years of exploitation, the expenses mark a slight increase.

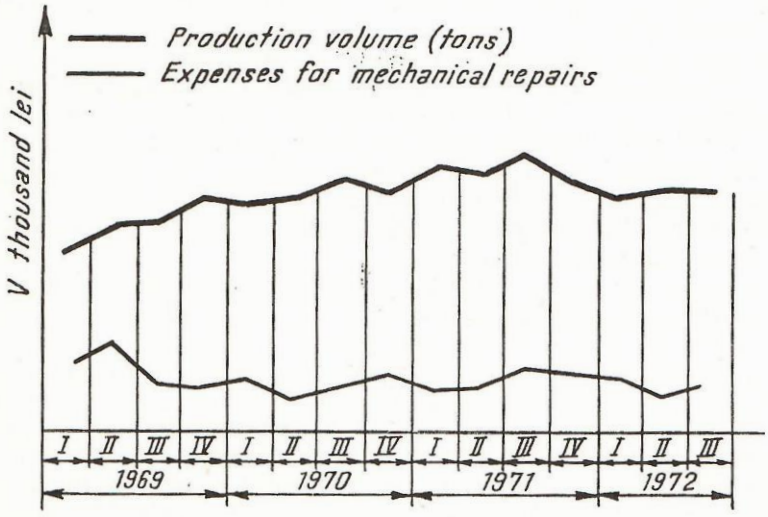


Fig. 2

This evolution attests to the fact that in the first functioning period, some parts and subensambles have untimely deteriorated because of some designing deficiencies and execution errors as well as because of the wrong

operations carried out by the exploitation staff which was not yet sufficiently trained.

The continuous improvement of the exploiting and maintenance conditions has led to a decrease of the maintainability expenses and to an increase in the volume of the production achieved.

Due to the fact that in the last two years an ever bigger number of parts and subensembles has been attaining the maximum limit of admissible wearings, the repair expenses have marked an increase, without surpassing, however, the initial limits.

The knowing of the general aspect of the frequency of the defects can give some indications only in connection with the opportuneness of the wearings or with the ampleness of the accidental defects.

But, these elements are insufficient for elaborating some concrete repair programmes.

Consequently, it is necessary to carry out verifications and measurings on the reliability of each component part or subensemble the characteristics of which cannot be inferred from the records made for the equipment as a whole.

At the same time, the statistical study of reliability can be useful only in case that each stage is accompanied by the examination of the physical causes provoking some phenomena or another. The formal application of the statistical methods for the study of reliability usually leads to erroneous results.

### 3. THE DURABILITY IN EXPLOITATION OF THE PARTS AND SUBENSEMBLES MAKING UP THE IRON AND STEEL EQUIPMENT

During their exploitation, the machines and installations lose their capacity of good functioning because of the deterioration of the component parts and subensembles.

This may take place instantaneously or gradually.

In the first case, the loss of the capacity of good functioning appears as an accidental, unforeseeable phenomenon, a situation obliging the enterprise to ensure corresponding stocks of safety parts for the prompt replacement of the elements out of order, in the second case, the replacement of the parts can be made preventively, in a planned way.

The knowing of the length of service of the machine parts is of particular technical and economic importance.

The scientific programming of the maintenance and repair activity cannot be made without the previous knowing of the length of service of the parts and subensembles making up the equipment.

Even if the methods for determining the durability of some of the elements do not ensure the obtaining of rigorously exact data, however, they allow a more real substantiation of the preparation and unfolding of the activity of the maintenance and repair compartments.

The rather high level of halts for accidental repairs is due to a great extent to the ignorance of the length of service of the parts and subensembles and thus, to their preventive non-replacing, which leads to the damaging of the equipment and to the registering of considerable financial and production losses.

The expenses for the removal of an accidental defect are too big in comparison with those necessary for a preventive replacement of the elements

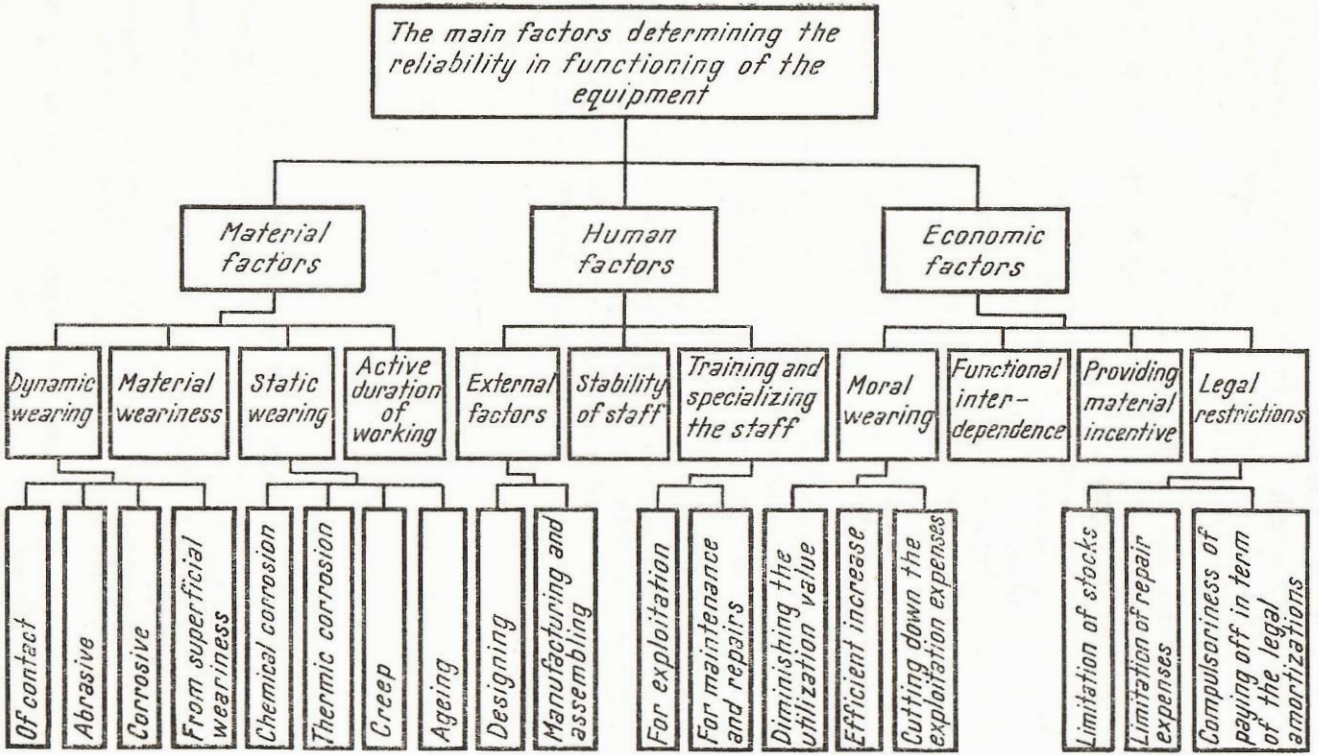
The main factors determining the reliability in functioning of the equipment
Material factors
Human factors
Economic factors
Dynamic wearing
Material weariness
Static wearing
Active duration of working
External factors
Stability of staff
Training and specializing the staff
Moral wearing
Functional inter-dependence
Providing material incentive
Legal restrictions
Of contact
Abrasive
Corrosive
From superficial weariness
Chemical corrosion
Thermic corrosion
Creep
Ageing
Designing
Manufacturing and assembling
For exploitation
For maintenance and repairs
Diminishing the utilization value
Efficient increase
Cutting down the exploitation expenses
Limitation of stocks
Limitation of repair expenses
Compulsoriness of paying off in term of the legal amortizations

Fig. 3

and they cannot by far be compensated by the prolongation of their exploitation up to a complete deterioration.

The knowing of the length of service of the parts and subensembles also allows the orientation of the staff in the chief-engineering compartment towards the increasing reliability of the feeble elements through their constructive and technological re-designing by developing a large collaboration with the specialized research and designing institutes.

The main factors determining the durability in exploitation of the elements are presented in Figure 3.

The annual deterioration caused by the wear of the machines and installations is estimated, on a world plane, to be equal to the destruction up to 20% of their total number. In the iron and steel industry, due to the intensive processes which are taking place and to some extremely difficult functioning conditions, the speed of deterioration of the parts and subsensembles attains high values.

The wear, expressed quantitatively, is a gradual process which can and must be attenuated for avoiding the untimely putting of the machines out of action.

As the length of service of each part is a random size, the statistical approach to this problem is necessary.

The determination of that length of service which is attained by 90% of the spare parts of the studied type is considered acceptible.

The statistical properties of the random variable representing the length of service of the machine parts, can be properly expressed through the Weibull distribution. The determination of the statistical parameters of this distribution is made through an adequate processing of the experimental data.

In its most general form, the Weibull distribution function has the following aspect:

$$p(t) = exp\,[-\,k(t - t_0)^{\nu}] \tag{3}$$

which, by a simple substitution, may be brought to the form:

$$P(t) = exp(-\,kt^{\nu}) \tag{4}$$

where:

- $t$ is the length of the examined parts or subensembles;
- $t_0$ — the length of service attained with certainty by each part or subsensemble;
- $P(t)$ — the probability for the part or subensemble to reach the length of life $t$;
- $k$, $\nu$, — the functional parameters of Weibull distribution characteristic of a certain type of part and exploiting conditions.

To determine these parameters, the length of service of n parts of a certain type is established in an increasing order, so that:

$$t_1, t_2 \ldots t_i \ldots . t_n$$

In this case, the probability $P_i$ to be attained, the length of life $t_i$ can be sufficiently well expressed with the formula:

$$P_i = 1 - \frac{i}{n+1} \; i = 1,2, \ldots, n \tag{5}$$

If one admitts that probability $P(t)$ can be calculated according to the Weibull distribution, then the succession of the probabilities $P(t_1)$, $P(t_2)$. . ., $P(_nt)$, calculated according to this distribution corresponds to the succession of the values $t_1$, $t_2$, . ., $t_n$.

The parameters of the Weibull distribution must be calculated so as the avarage square error is minimum, that is:

$$\sum_{i=1}^{n} [P_i - P(t_i)]^2 \to min. \tag{6}$$

In the case of the biparametrical distribution, $k$ and $\nu$ should also be determined, so that:

$$F(\nu, k) = \sum_{i=1}^{n} [P_i - exp(- kt_i)]^2 \to min \tag{7}$$

If instead of the condition of the form (6), the condition

$$\sum_{i=1}^{n} \left[ \ln \ln \frac{1}{p_i} - \ln \ln \frac{1}{P(t_i)} \right]^2 \to min \tag{8}$$

is necessary, the same results are obtained, but, with a much more reduced volume of calculations.

By logarithmizing twice the formula (4), we obtain:

$$\ln \ln \frac{1}{P(t)} = \ln k + \nu \ln t \tag{9}$$

Condition (8) becomes:

$$F(k, \nu) = \sum_{i=1}^{n} \left[ \ln \ln \frac{1}{P_i} - (\ln k + \ln t_i) \right]^2 \to min \tag{10}$$

By using the notations:

$$y_i = \ln \ln \frac{1}{P_i}; \qquad x_i = \ln t_i \tag{11}$$

$$a_1 = \ln k; \qquad a_2 = \nu$$

formula (10) becomes:

$$F(a_1, a_2) = \sum_{i=1}^{n} (y_i - a_1 - a_2 x_i)^2 \to min. \tag{12}$$

The minimum conditions for relation (12) are:

$$\frac{\partial F}{\partial a_i} = 0; \qquad \frac{\partial F}{\partial a_2} = 0 \tag{13}$$

which lead to the system of linear equations:

$$\begin{cases} na_1 + \left(\sum_{i=1}^{n} x_i\right) a_2 = \sum_{i=1}^{n} y_i & (14) \\ \left(\sum_{i=1}^{n} x_i\right) a_1 + \left(\sum_{i=1}^{n} x_i^2\right) a_2 = \sum_{i=1}^{n} x_i y_i & (15) \end{cases}$$

with the solution:

$$a_1 = \frac{\sum_{i=1}^{n} y_i \sum_{i=1}^{n} x_i^2 - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} x_i y_i}{n \sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2} \tag{16}$$

$$a_2 = \frac{n \sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} y_i \sum_{i=1}^{n} x_i}{n \sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2}. \tag{17}$$

The use of the electronic computer for establishing the Weibull distribution parameters and respectively the length of service of the parts and subensembles whose exploitation is followed statistically is considerably reducing the duration of the necessary calculations.

For this, we have initiated the elaboration of some programmes written in the FORTRAN IV language, which were tested on the IBM 360/30 computer at the Computing Centre of the Bucharest University.

The statistical methods allow the establishment, with greater precision than the analytical calculations, of the length of service of the analysed elements. But, the analytical computing methods should not be neglected either, because they can show the first estimation of the length of service of the parts and subensembles fitted up on the new installations, about which, however, we do not have sufficient data from exploitation for an adequate statistical estimation. At the same time, the analytical computing relations are those which explicitely present the factors limiting the length of service of some parts and subsenembles, allowing the taking of adequate measures in view of increasing their reliability.

Consequently, parallel with the statistical estimations of the length of service for the expensive machine parts with a relatively reduced durability in exploitation, it is necessary to elaborate and examine some adequate analytical computing relations.

The static wear is also a gradual process which allows, based on systematic controls, to take adequate steps for preventing damages.

The other factors causing the sudden putting of some parts and subensembles out of action have an unforeseeable random frequency which do not lend themselves to be estimated by analytical calculations.

For this reason, they cannot be taken into consideration in determining the length of service of the respective machine parts, in view of elaborating preventive repair programmes.

The effects of the action of these factors are the accidental halts.

Statistical studies of the past few years have shown that the accidental defects may also be characterized by some distribution laws (Poisson, Gamma), allowing the fundamental dimensioning of the stock of the necessary safety parts.

## REFERENCES


1. NICOLAE CEAUŞESCU: *Raportul C.C al P.C.R. cu privire la activitatea P.C.R. în perioada dintre Congresul al VIII-lea şi Congresul al IX-lea.* (Report of the Central Committee of the Romanian Communist Party on the Activity of the Romanian Communist Party for Period between the 8th and the 9th Congresses.) Editura politică, Bucharest, 1965.
2. NICOLAE CEAUŞESCU: *Raportul C.C. al P.C.R. cu privire la activitatea P.C.R. în perioada dintre Congresul al IX-lea şi Congresul al X-lea şi sarcinile de viitor ale partidului.* (Report of the Central Committee of the Romanian Communist Party on the Activity of the Romanian Communist Party for Period between the 9th and the 10 th Congresses and the Future Tasks of the Party). Editura politică, Bucharest, 1970.
3. NICOLAE CEAUŞESCU: *Raport la Conferinţa Naţională a Partidului Comunist Român.* (Report to the National Conference of the Romanian Communist Party). Editura politică, Bucharest, 1972.
4. * * * * *Legea nr. 62/1968,* publicată în Buletinul oficial al R.S.R., (Law no. 62/1968, published in the Official Bulletin of the Socialist Republic of Romania), no. 14 of January 29th, 1969.
5. BENESCU VASILE and his collective: *Raţionalizarea calculelor în proiectare.* (Rationalization of Calculuses in Designing), Editura tehnică, Bucharest, 1970.
6. BOGAŢIU I. V. and KRAVŢOV I. I.: *Metode pentru calculul necesarului de piese de rezervă pentru utilajele în funcţiune.* (Methods for Calculating the Necessary Spare Parts for the Working Installations). Standardî i kacestvo, Moscow, no. 7, 1971.
7. BÖCKNER A.: *Întreţinerea preventivă planificată.* (Planned Preventive Maintenance). Industrie-Anzeiger, the Federal Republic of Germany, no. 35, 1970.
8. BÖTTCHER SIEGFRID: *Solicitări dinamice şi evoluţia lor în timp, efectul lor asupra duratei de viaţă şi disponibilităţii utilajelor siderurgice.* (Dynamic Stress and its Evolution in Time, its Effect on the Length of Life and the Availability of Iron and Steel Equipment). Eisen, no. 8, the Federal Republic of Germany, 1970.
9. BÖTTCHER SIEGFRID: *Solicitări dinamice şi evoluţia lor în timp, efectul lor asupra duratei de viaţă şi disponibilităţii utilajelor siderurgice.* (Dynamic Stress and its Evolution in-Time, its Effect on the Length of Life and on the Availability of Iron and Steel Equipment), Stahl und Eisen, no. 8, 1972.
10. BUZDUGAN GHEORGHE: *Rezistenţa materialelor.* (The Resistance of Materials). Editura didactică şi pedagogică, Bucharest, 1964.
11. DIETER E. GEORGE: *Metalurgia mecanică* (Mechanical Engineering). Translation from English, U.S.A., I.D.T., Bucharest, 1970.
12. DRUJININ G. V.: *Siguranţa în funcţionarea sistematică.* (Reliabibility in Systematic Functioning), Editura tehnică, Bucharest, 1968. (Translation from Russian after the second edition, completed and revised).
13. DOLAZZA ENRICO: *Fiabilitatea şi întreţinerea.* (Reliability and Maintenance). Manutenzione Industriale Transporti, Rome, no. 12, 1969.

14. GHEORGHE VASILICA and BÎȚA OLGA: *Procese de lubreficație, frecare și uzură la suprafețele metalice.* (Lubrication, Friction and Wear Processes on Metallic Surfaces). Editura Academiei R.S.R. Bucharest, 1967.
15. GRÄHER P. and SCHUSTER M.: *Uzura și siguranța în exploatare a agregatelor de construcții și a mașinilor de transport.* (The Wear and Exploiting Reliability of Building Aggregates and of Transport Machines). I.D.T. Întreținerea și repararea mașinilor și utilajelor No. 3/1971 (translation from German).
16. HEMELIN RUVEN: *Determinarea randamentului personalului de întreținere.* (Determining the Efficiency of the Maintenance Personnel). Maintenance Engineering, Paris, May, 1968.
17. IVANOV N. P. and NOSCIN P.A.: *Perfecționarea organizării reparațiilor.* (Improving the Organization of Repair Works), I.D.T., Bucharest, 1969.
18. LAZARU M. ION: *Metode și mijloace pentru asigurarea duratei optime de funcționare a utilajelor.* (Ways and Means for Ensuring the Best Functioning Duration of Installations). I.D.T. Bucharest, 1969.
19. KALTENBORN A.: *Valorificarea matematică a încercărilor de durată de viață (a elementelor de mașini) cu ajutorul calculatoarelor.* (Mathematical Check of Life Length Tests (of Machine Parts) with the Aid of Computers). Translation from Machinenbautechnik, Leipzig, the German Democratic Republic, no. 8, 1970.
20. The Ministry of Heavy Industry: *Repararea mijloacelor de bază.* (Repair of Basic Means), Editura Agro-silvică, Bucharest, 1959.
21. The Ministry of Metallurgical Industry: *Norme tehnice pentru repararea mașinilor, utilajelor și instalațiilor pentru metalurgia feroasă, inclusiv pentru laminarea și trefilarea metalelor neferoase* (codul 403) (Technical Standards for Repairing the Machinery, Equipment and Installations for Ferrous Metallurgy, for the Rolling and Wire-drawing of Non-ferrous Metals Inclusively (code 403), CDPT, Bucharest, 1970.
22. The Ministry of Labour: *Îndrumar metodologic privind raționalizarea circulației informațiilor.* (Methodological Guide on the Rationalization of Data Circulation). CDP—MM, Bucharest, 1972.
23. MAYNARD H. B.: *Conducerea activității economice.* (Management of Economic Activity), vol. 2, Editura tehnică, Bucharest, 1971 (translation from English), U.S.A.
24. MENDELOVICI MARIUS: *Înmagazinarea și regăsirea informațiilor,* (Data Storing and Retrieval), vol. 1, CNST—I.D.T., Bucharest, 1972.
25. MANEA GHEORGHE: *Organe de mașini* (Machine Elements), Editura tehnică, Bucharest, 1970.
26. MĂTARE I. and GHEORGHIU GH.: *Îndrumătorul mecanicului șef.* (The Chief Engineer's Guide), Editura Agro-silvică, Bucharest, 1959.
27. MELLEROWICZ K: *Posibilitatea reducerii cheltuielilor de exploatare luîndu-se în considerare reparația și ungerea mașinilor.* (The Possibility of Reducing the Exploiting Expenses by Taking into Consideration the Rapair and Greasing of Machines), Maschinen Schaden, the Federal Republic of Germany, no. 5, 1967.
28. MELLEROWICZ K: *Politica costurilor și evidența cheltuielilor în lucrările de întreținere.* (The Policy of Costs and the Keeping Accounts of Expenses in Maintenance Work). V.D.I. Berichte, the Federal Republic of Germany, no. 131, 1968.
29. MORISON C. T. and SIMPSON V. A.: *O metodă economică de întreținere pentru ansamblurile de cilindri de la laminorul de benzi la cald.* (An Economical Maintenance Method for the Ensembles of Cylinders at the Hot Strip Mill). I.D.T. Întreținerea și repararea utilajelor. no. 6., 1971.
30. MĂRGĂRITA VALENTIN: *Utilizarea radioizotopilor în industrie* (Utilization of Radioisotopes in Industry), ICDT, Bucharest, 1972.
31. NICULESCU D: *Siguranța în funcționare a mașinilor, aparatelor, utilajelor și instalațiilor tehnologice.* (The Reliability of the Machines, Apparatus, Equipment and Technological Installations). Calitatea producției și metrologie. Bucharest, no. 1, 1972.
32. PAVELESCU DAN: *Concepții noi, calcule și aplicații în frecarea și uzarea solidelor deformabile.* (New Concepts, Calculuses and Applications in the Friction and Wear of Deformable Solids). Editura Academiei R.S.R., 1971.
33. PRONIKOV S. A.: *Uzura și durabilitatea mașinilor unelte.* (The Wear and Durability of Machine Tools), I.D.T., Translation from Russian, Bucharest, 1958.
34. PRONIKOV S. A.: *Organizarea reparației capitale a unui furnal în Anglia.* (Organization of Capital Repairs of a Furnace in Great Britain). B.I.T. Documentare metalurgică, nr. 8, 1968. Furnale.

35. REDEKER G: *Durata de funcţionare a utilajelor şi instalaţiilor, un criteriu important pentru planificarea întreţinerii utilajelor.* (The Functioning Duration of Equipment and Installations, an Important Criterion for Planning the Maintenance of Installations). Metall Internationalle Zeitschrift für Tehnik Wirtschaft, the Federal Republic of Germany, no. 8, 1970.
36. REŞETOV D. N.: *Organe de maşini.* (Machine Parts), Editura tehnică, Bucharest, 1963. (translation from Russian).
37. RENKES D: *Organizarea şi planificarea întreţinerii în uzinele siderurgice.* (Organization and Planning of Maintenance in the Iron and Steel Works), Stahl und Eisen, the Federal Republic of Germany, 1969.
38. SELEŞTEANU ALEXANDRU: *Durata de viaţă a maşinilor.* (The Length of Life of Machinery), I.D.T. Metalurgia şi construcţia de maşini. Bucharest, no. 1, 1967.
39. SELEŞTEANU ALEXANDRU: *Principii şi metode de proiectare a maşinilor.* (Principles and Methods for Machinery Designing), Editura tehnică, Bucharest, 1969
40. TOMESCU C: *Prevenirea avariilor la maşini şi instalaţii.* (Preventing Damages at Machines and Installations), I.D.T. Revista de sinteze documentare, Bucharest, 1970.
41. TĂRĂBOI VASILE: *Calculul de durabilitate a organelor de maşini.* (Calculus for the Durability of Machine Parts), I.D.T., Bucharest, 1957.
42. VISINTINI M: *Méthodes actuelles d'entretien.* France, 1966.
43. VALDMAN A: *Un sistem raţional de reparaţii.* (A Rational Repair System). Ekonomiceskie nauki., Moscow, no. 3, 1968.
44. WEISS W. H.: *Determinarea echipelor de întreţinere.* (Establishing the Maintenance Teams). Maintenance Engineering, France, 1968.
45. ZEZOWSKI A: *Calculatoare numerice utilizate la pregătirea tehnică a producţiei de piese de schimb.* (Digit Computers used in the Technical Preparation of the Spare Parts Production). Mechanik, Warsaw, no. 10, 1970.
46. * * * *Gestionarea stocurilor de piese de schimb.* (Management of the Spare Parts Stocks). The Trade-Union House of French Iron and Steel Industry, 1969.
47. * * * *Organizarea întreţinerii şi reparaţiilor la utilajele din uzinele siderurgice din R. P. Polonă.* (Organization of Engineering Maintenance and Repairs at the Installations in the Iron and Steel Works in the Polish People's Republic). I.D.T. Documentare metalurgică. Organizare, Bucharest, no. 4, 1968.
48. * * *: *Îmbunătăţirea sistemului de reparaţii preventiv planificate.* (Improving the Planned Preventive Repair System). I.D.T., Organizarea ştiinţifică a producţiei, Bucharest, no. 10, 1968.
49. * * *: *Programarea întreţinerii în siderurgie.* (Programming of Maintenance in the Iron and Steel Industry.) Iron and Steel Engineering, the Federal Republic of Germany, no. 6, 1968.
50. * * *: *Controlul întreţinerii preventive.* (The Check of Preventive Maintenance). Blast furnace and steel plant, the Federal Republic of Germany, no. 6, 1968.
51. * * *: *Aspectul tehnico-economic al întreţinerii.* (The Technical-Economic Aspect of Maintenance). I.D.T. Întreţinerea şi repararea utilajelor, Bucharest, no. 8, 1968.
52. * * *: *Norme organizatorice ale întreţinerii.* (Organizational Standards for Maintenance). I.D.T. Întreţinerea şi repararea utilajelor, Bucharest, no. 7, 1968.
53. * * *: *Raţionalizarea în întreţinere.* (Rationalization in Maintenance), Maschinenbau, the Federal Republic of Germany, no. 4, 1968.
54. * * *: *Rentabilitatea pregătirii lucrărilor de întreţinere.* (The Profitableness in Preparing Maintenance Work). I.D.T. Întreţinerea şi repararea utilajelor, Bucharest, no. 6, 1968.
55. * * *: *Organizarea reparaţiilor centralizate ale utilajului electric la Combinatul siderurgic din Magnitogorsc.* (Organization of Centralized Repairs of the Electric Equipment at the Magnitogorsc Iron and Steel Works), Stahl, the German Democratic Republic, no. 5, 1968.
56. * * * Cum se calculează rentabilitatea unei întreţineri preventive. (How is the Profitableness of a Preventive Maintenance Being Calculated). Revue technique de l'entretien et des travaux neufs, Paris, no. 183, 1967.
57. * * * Întreţinerea echipamentului. (Equipment Maintenance). Travail et méthodes, Paris, 1967.
58. * * * De l'entretien à la maintenance industrielle. Travail et méthodes, Paris, 1967.

## ACCROISSEMENT DE L'EFFICACITE DE L'ACTIVITE DE REPARATIONS DE L'EQUIPEMENT SIDERURGIQUE

Compte tenu de l'importance toute particulière, ainsi que du degré élevé d'efficience qu'un programme optimal de réparations peut offrir, cet ouvrage tente à établir des modèles mathématiques en déterminant ses éléments fondamentaux. À cet effet on emploie tant les méthodes du calcul classique, que celles que la statistique mathématique et la théorie des probabilités nous mettent à disposition à l'heure actuelle.

Bien que les principes généraux qui y sont exposés trouvent une large application dans toutes les branches de la production matérielle, les études concrètes et les applications présentées portent sur le matériel d'équipement spécifique à l'industrie sidérurgique, tenant compte de la complexité et de la valeur élevée, du degré d'intégration, de mécanisation et d'automation des processus.

A titre d'exemple fut choisi l'équipement principal du Combinat sidérurgique „Gh. Gheorghiu-Dej" de Galatzi, l'unité la plus moderne de notre industrie sidérurgique, qui d'ici 3—4 années occupera la première place dans la production d'acier et de produits laminés. De l'ensemble du matériel d'équipement et des installations, l'auteur s'attache à étudier l'activité d'entretien et de réparation des outillages mécaniques, ceux-ci ayant un poids principal dans la structure des moyens fixes.

## ПОВЫШЕНИЕ ЭФФЕКТИВНОСТИ ДЕЯТЕЛЬНОСТИ ПО РЕМОНТУ ОБОРУДОВАНИЯ ЧЕРНОЙ МЕТАЛЛУРГИИ

С учетом особого значения и высокой эффективности, которую может обеспечить оптимальное программирование ремонта, в настоящей статье делается попытка математического моделирования этой задачи и определения элементов обоснования с применением как классических методов расчета, так и методов, которые математическая статистика и теория вероятности предоставляют в наше распоряжение в настоящее время.

Несмотря на то, что общие принципы, приводимые в дальнейшем, имеют широкую применяемость во всех отраслях материального производства, приводимое конкретное изучение и применение были разработаны для оборудования, специфического для черной металлургии, с учетом его комплексности и высокой стоимости, степени интеграции, механизации и автоматизации процессов.

Для примера были приведены основные виды оборудования Галацкого металлургического комбината имени Г. Георгиу-Деж — наиболее современного предприятия нашей черной металлургии, которое в последующие 3—4 года займет первое место по производству стали и проката в стране. Из всего оборудования и установок, имеющихся на оснащении, в статье рассматривается деятельность по содержанию и ремонту механического оборудования, имеющего наибольший удельный вес в структуре основных средств.