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THE REGENERATION OF SOME ROLLERS SYSTEM ON THE FLEXIBLE ROLLING-MILL LINE

Summary. The paper present the regeneration process of some rollers on the Flexible Rolling-Mill Line (FRL), which in the system with in series/parallel structure of the buffer store is described. To solve the problem, we used the multistage programming method.

1. Introduction

The system of the Flexible Rolling Line (FRL) is composed of the FRL with the buffer stores placed at the entry and exit of the FRL [1, 3] and of the system regeneration of the rollers (fig. 1).

The FRL is assumed to be fed with random lots of charge at random moments of time. Various assortments are conveyed from FRL to the buffer stores having limited capacity, from which material is taken out at random moments and random lots. In the buffer store, the charge reserves are restocked by a charge mass flow at a constant time. The FRL products are conveyed by portions to the further units. These units should be operated continuously. Buffer stores for proper products are provided before them to ensure that the units are operated continuously. The product of one type can be located in each buffer store. The absence of product causes specified production losses. Concurrent production of different assortments on the FRL necessitates tool replacement and the line down-time.

The paper present a problem of replacement some rollers in the regeneration process of the assembly of the passes on the FRL, which in the system with in series/parallel structure of the buffer store is described. To solve the problem, we used the multistage programming method.

2. The description of the regeneration rollers process

The feature of the FRL is sequential manufacturing the products of various range of goods on the same line. A proper tools is needed for each assortment and particular line unit. The production of different range of goods is related to the necessity of tool replacement (assemblies of the passes). It is assumed that the tools are multifunctional, i.e. they can be used for manufacturing various assortments. The tool replacement causes FRL shut-downs, which decreases its effectiveness. To accomplish such a manufacturing process, replacements of tools and working programmes of the FRL are necessary.

In the replacement of the roller process is assuming, that the substitute roller (the doubler) in the replacement time is accesibled. The scheduling of the rolling process is run aheading the times of the ended of the regeneration of the assemblies rollers.

In the time of the rolling process the operative surface of the passes is wearing, in consequence the quality of the assortment products is decreasing. For the elimination this fact is using the correction of the working rollers on the way of the passes replacement to the same, but no substituted or on the way of the replacement interchangeable of the assemblies of the rollers.

In the rolling process are taking part two assembly of the rollers: the basical roller and the doubler. The worn out roller is replacement and puting to the regeneration process. In the time of the rolling process of the basical roller, the doubler is regenerating. The regeneration time of the

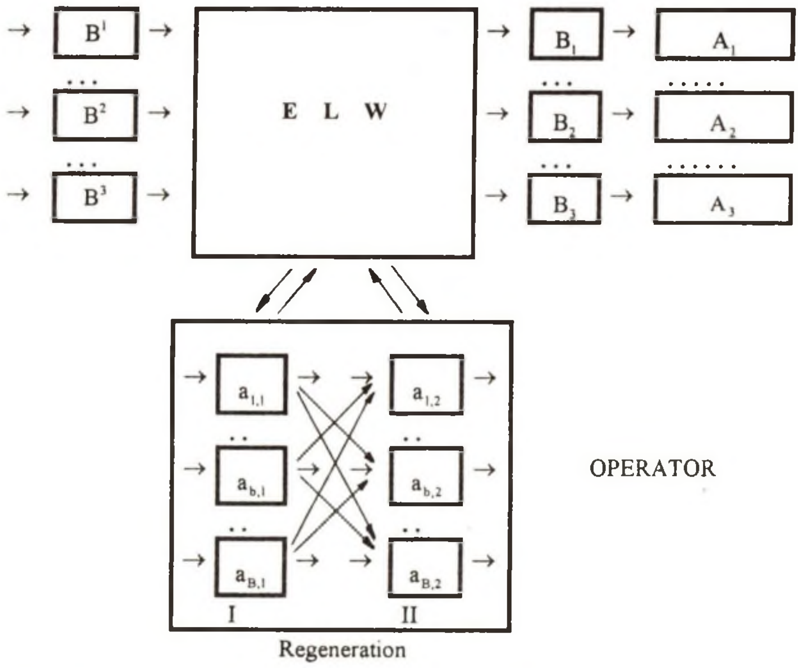

Fig.1. FRL (A_n - n-th aggregate, B_n - n-th output buffer store,
N - number of aggregates (stores or produkts),
B^m - m-th buffer input store, M - number of charge types.)

roller and the more late time of the ending of the regeneration are resulting from the schedule of the rolling process. The regeneration process are consisting of two phase: the building up of the worn out surfaces and the turning to the determined sizes. For this purpose is using the parallel unit of the padders, which are connected in series with the parallel units of the roll-tuning lathe. For every rollers type is determined the alternate technological route, which are going under the determined padder and the roll-turning lathe. Moreover, the working time is on every aggregate (on the padder work and on the lathe work) determined. From this is the in series/parallel structure of the regeneration system resulting.

For the purpose of the performing requirements of the rolling schedule, one should calculate the schedule of the regeneration. The regeneration schedule is determined the time range for every roller, in which the roller is working on the determined padder and the roll-turning lathe. In this situation is assuming, the rolling schedule can not be changed. In the practice, for every regenerated of the roller is making efforts by determined time shake (the end of the regeneration before the time). For this described work task may be determining the optimal minimax of the regeneration scheduling criterion, described the mathematical model and the algorithm of the scheduling [2].

The shut - down of the FRL for the replacement of the rollers is prooduction losses specified. From this on the real FRL the replacement of the rollers are operating to:

- - the new regenerated assembly rollers, with the same passes as the worn out assembly rollers,
- - the doubler, with the new regenerated of the j-th pass,
- - the assembly rollers, with the different tolerance of the passes in the assembly rollers,
- '- the doubler, with the different tolerance of the passes in the assembly rollers,
- - the assembly roller, with the new regenerated of the j-th pass and with the different passes in the assembly rollers,
- - the doubler, with the new regenerated of the j-th pass and with the different passes in the assembly rollers.

3. Mathematical model of the regeneration rollers system

The regeneration of the rollers system is a system with the strukture in series/parallel, composite from two subsystems connected in series. Every subsystem is the parallel configuration of the working aggregates.

The solving of the analized problem can be for two cases: system with central buffer store and system with some local buffer stores (rys.2.a,b).

3.1.Basic definitions and assumptions

Def.1: The aggregates set are given in form:

$$A = [a_{p,r}] \qquad p=1,..,M_r \qquad r=1,2 \tag{1}$$

where: $a_{p,r}$ - p-th aggregate of the r-th system,

M_r - number of the aggregates in the r-th system.

Def.2.: The work tasks set are given in the form:

$$\Omega = \{\omega_n\} \tag{2}$$

where: ω_n - n-th object, N - number of the product type.
The object in the analized problem is the regeneration of the roller.

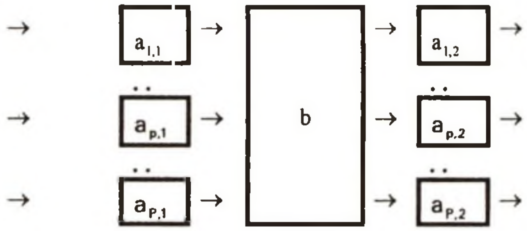

Fig.2.a.The system with the central buffer store.

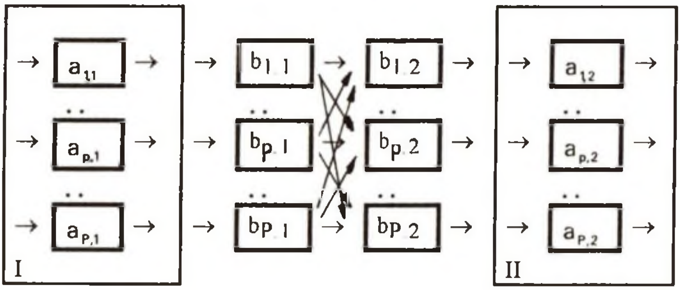

Fig.2.b. The system with some local buffer stores

We shall assume that alternate technological routes of the work taskes by the aggregates. Every object (the roller) is sequential obtained to one aggregate of 1-th subsystem (the padder) and to one aggregate of 2-nd subsystem (the lathe).

Def.3.: The realizalibity of the work task in the n-th aggregate expressed by matrix:

$$U_r = \left[u^r_{p,n}\right] \tag{3}$$

where:

$$u^r_{p,n} = \begin{cases} 1, & \text{if } \omega_n \text{ can be realized on the aggregate } a_{p,r} \\ 0, & \text{otherwise} \end{cases} \tag{3a}$$

Def.4.: The times for every object in the subsystem are given in the matrix:

$$\tau^r = \left[\tau^r_{p,n}\right] \tag{4}$$

where: $\tau^r_{p,n}$ - time for n-th object in r-th subsystem on the p-th aggregate.

Def.5: The operations times in the object are given in the matrix:

$$\chi^r = \left[\chi^r_p\right] \tag{5}$$

where: χ^r_p - time of the operation in the object for p-th aggregate in r-th subsystem.

We shall assume that <u>times of the work task realization in the individual aggregates</u> are given in the matrix:

$$\Theta = \left[\vartheta^{r}_{p,n}\right] \tag{6}$$

where: $\vartheta^{r}_{p,n}$ - time of work task realization ω_n on the aggegate $a_{p,r}$.

Let us assume that <u>access times aggregates in start condition</u> are given in the matrix:

$$\Phi_r = \left[\varphi^{r}_{p,n}\right] \tag{7}$$

where: $\varphi^{r}_{p,n}$ - access time of the work task for the aggregate $a_{p,r}$.

Let us assume that <u>access times of the work task</u> are given in the vector:

$$T = \left[t_n\right] \tag{8}$$

where: t_n - access time of the work task ω_n.

Def.6: <u>The more late ending times of the task work realization</u> are given in the vector:

$$\Xi = \left[\xi_n\right] \tag{9}$$

where: ξ_n - the more late ending time of the work task work realization ω_n.

Def.7: <u>The ending times of the task work servicing in the systems and in the aggregates are given in matrix</u>:

$$\Psi_r = \left[\psi^{r}_{p,n}\right] \tag{10}$$

where: $\psi^{r}_{p,n}$ - the more late ending time of the task work realization ω_n for the aggregate $a_{p,r}$.

The time t_n can not be advanced and the time ξ_n can not be execed.

We will analizing the period of the schedule from the time t_0 to the time t^0. The work task will be the regeneration of the rollers in the time $(t_0 - t^0)$. In the time t^0 any task workes can waiting on the regeneration proces.

The work task ω_n must be preceding all the work taskes ω_n, for which are performed conditions:

$$\xi_n < t_n \tag{11}$$

The roller ω_v after the regeneration process to the time t_n is rolling of the m-th charge type, after which the roller ω_n must be replacement. From this the work task ω_n can not realized to the work task ω_v.

The analize of the times t_n and ξ_n in basic schedule of the FRL can be determine the <u>antecedent and consequent direct matrix in the r-th system</u>:

$$\Gamma = \left[\gamma^{r}_{v,n}\right] \qquad r=1,2 \tag{12}$$

where: $$\gamma^{r}_{v,n} = \begin{cases} 1, & \text{if } \omega_v \text{ is before } \omega_n \\ 0, & \text{otherwise} \end{cases} \tag{13}$$

We shall assume that τ_n is <u>the ending realization time of the work task ω_n</u>.

<u>The criterion of the optimal schedule of the work tasks</u> are given in the form:

$$Q = \min_{1 \le n \le N} \left(\xi_n - \tau_n\right) \to \max \tag{14}$$

The problem of the graphical scheduling can not have of the solution (ξ_n is limited). For existing of the solution of the problem, the criterion (14) is permiting calculate the scheduling of the maximization of the realization of the work tasks minimum.

The schedule of the rollers regeneration is given in the form:

$$H = \langle <>, \quad ...., \quad < \mu_m, t^1_{p,n}, m_n, t^2_{p,n} > \rangle \tag{15}$$

where: μ_m, m_n - number of the aggregates.

$t^1_{p,n}$, $t^2_{p,n}$ - moments of the ending work taskes on the aggregates of the 1-th subsystem and of the 2-th system.

The criterion of the rollers schedule regeneration is given in the form:

$$Q = \max_r \max_p \max_{1 \le n \le N} \left(t^r_{p,n} - \psi^r_{p,n} \right) \rightarrow \min \tag{16}$$

The acceptable schedule sould accomplished following conditions:

- the operation limitations and the continuity:

$$t^r_{p,n} = \varphi^r_{p,n} + \vartheta^r_{p,n} \tag{16a}$$

- in every times can be servicing only one object:

$$\left(t^r_{p,i} \le t^r_{p,j} \right) \wedge \left(t^r_{p,j} \le t^r_{p,i} \right) \tag{16b}$$

- the object of access is no late as the access time of the aggregate in the system:

$$\psi^r_{p,n} < \varphi^r_{p,n} \tag{16c}$$

- the succession relation:

$$\left(\gamma^r_{v,n} = 1 \right) \Rightarrow \left(t^r_{p,n} \le \varphi^r_{p,n} \right) \tag{16d}$$

3.2.The decision state of the process and value of the state

We shall assume the denotation as η (η=1,...,2N) the number decision stage and as λ (λ =1,...,L_η) the number of the state in the stage η (L_η - number of the states in η-th stage).

Def.8: The decision state of the FRL is given in the matrix:

$$X^{\eta,\lambda} = \left[x^{\eta,\lambda}_{n,s} \right] \qquad n=1,...,N \qquad s=1,...,4 \tag{17}$$

The elements of the matrix (17) are expressed as follows:

$$X^{\eta,\lambda} = \left[x^{\eta,\lambda}_{n,s} \right] \qquad n=1,...,N \qquad s=1,...,4 \tag{17a}$$

$$x^{\eta,\lambda}_{n,2} = \begin{cases} t_{\mu,n}, & \text{if } p^{\lambda,\eta}_{n,1} = \mu \\ 0, & \text{otherwise} \end{cases} \tag{17b}$$

$$x^{\eta,\lambda}_{n,3} = \begin{cases} p, & \text{if the work task } \omega_n \text{ is obtained} \\ 0, & \text{otherwise} \end{cases} \tag{17c}$$

$$x_{n,4}^{\eta,\lambda} = \begin{cases} t_{p,n}, & \text{if } p_{n,3}^{\lambda,\eta}, \\ 0, & \text{otherwise} \end{cases} \tag{17d}$$

where: $t_{\mu,n}$ - the ending time of the work task realization ω_n on the aggregate $a_{\mu,1}$,

$t_{b,n}$ - the ending time of the work task realization ω_n on the aggregate $a_{\mu,2}$,

From this, the start state $X^{0,1}$ is a zero matrix and the ending states $X^{2N,\lambda}$ are all positive elements. From every state $X^{\eta,\lambda}$ can be calculated the schedule of the work taskes realization, which are assign to the state.

Every state $X^{\eta,\lambda}$ is determined his value denotated as $V^{\eta,\lambda}$. The value of the state is determined by the criterion (14, 16).

Def.9: The value of the state is calculated from the condition:

$$V^{\eta,\lambda} = \max_{n \in \alpha^{\eta,\lambda}} \left(\xi_n - x_{n,4}^{\eta,\lambda}\right) \tag{18}$$

and:

$$\underset{n}{\forall} \left(x_{n,4}^{\eta,\lambda} > 0\right) \Rightarrow \left(n \in \alpha^{\eta,\lambda}\right) \tag{19}$$

The value of the state $X^{1,0}$ is zero. The value of every ending state $X^{2N,\lambda}$ is the minimum advanced time (for ones from the work taskes). From the criterion (14, 16) the optimal ending state is calculated from condition:

$$\left(\max_{1 \le \lambda \le L_{N,2}} V^{2N,\lambda} = V^{2N,\lambda^0}\right) \Rightarrow \left(X^{2N,\lambda^0} = X^0\right) \tag{20}$$

where: X^0 - the optimal state.

From the optimal state can be reading the optimal schedule of the work tasks realization.

3.3.The generation of the states

The procedure of the generation of the states is consisting on the completion of the state $X^{\eta-1,l}$ by the work task ω_n this way, on which can be to give the acceptable state $X^{\eta,l}$. One should to pay attention to the fact, that the work task ω_n, which are assigning to the aggregate $a_{\mu,1}$ and all work taskes ω_n for which $\gamma_{v,n}$=1, must be realized in the 2-th subsystem. Moreover, if the work task ω_n is assigning to the aggregate $a_{\mu,2}$, we not checking the precedence constraints, becouse all some antecedent ω_n must be realized in the 1-th subsystem.

In the generation of the states we introducing the chronological order, i.e. the recording time, in which are the events in the buffer stere (the influx and low tide of the object from the buffer store).

Let us $C^{\eta-1,\lambda}$ the last event, which was in the buffer store:

Than

$$X^{\eta-1,l} = C^{\eta-1,\lambda} \tag{21}$$

For working aggregates of 1-th subsystem and of 2-nd subsystem:

$$C^{\eta,\lambda} = t_{\mu,n}^{1} \tag{22}$$

$$C^{\eta,\lambda} = t_{\mu,n}^{2} - \vartheta_{m,v}^{2} \tag{23}$$

From the parameter $C^{\eta,\lambda}$ can not information by the influx and by the low tide of some objects from the buffer store. For this information must be following cases:

- - if the object is delivered to the buffer store after making of the operation in the 1-th subsystem, then: $C^{\eta-1,\lambda} > 0$,
- - if the object is displacement from the buffer store to making of the operation in the 2-th subsystem, then $C^{\eta-1,\lambda} < 0$.

The starting state: $C^{0,l} = 0$ and $|C^{e,l}| \geq |C^{f,\lambda}|$

where: $e > f$ is denoteted, that on the late stages the times must be more late.

Let as assume, that $F_r^{l,\eta-1}$ is the access time of the r-th subsystem in the state $X^{\eta-1,l}$.

$$F_r^{l,\eta-1} = \min_{1 \leq p \leq M_r} t_{r,p}^{l,\eta-1} \tag{24}$$

$$\text{where:} \quad t_{r,p}^{l,\eta-1} = \begin{cases} r_{r,p} = \left|\alpha_p^{l,\eta-1}\right| = 0, \\ \max\limits_{i \in \alpha_m^{l,\eta-1}} x_i^{l,\eta-1}, & \text{otherwise} \end{cases} \tag{24a}$$

$$\text{and} \quad \forall_n \quad \left(x_{i,2r-1}^{l,\eta-1} = m\right) \Rightarrow \left(i \in \alpha_p^{l,\eta-1}\right) \tag{24b}$$

For the regeneration of the rollers system with the central buffer store are calculating:

$$t_{p,n}^1 = x_{n,2}^{2N,l} \qquad \varphi_{p,n}^1 = t_{p,n}^1 - \vartheta_{p,n}^1 \qquad m_n = x_{n,3}^{2N,l} \tag{25a}$$

$$t_{p,n}^2 = x_{n,4}^{2N,l} \qquad \varphi_{p,n}^2 = t_{p,n}^2 - \vartheta_{p,n}^2 \tag{25e}$$

$$V^{\eta,\lambda} = \max\left(x_{n,j}^{\eta,l} - \psi_{p,n}^r\right)\Big|_{j=2,4;} \quad r = 1,2; \quad m = \begin{cases} x_{n,1}^{\eta,l}, & r = 1 \\ x_{n,3}^{\eta,l}, & r = 2 \end{cases} \tag{26}$$

$$\text{or recurrent:} \quad V^{\eta,l} = \begin{cases} V^{\eta-1,\lambda}, & \text{if} \quad t_{p,n}^r - \psi_{p,n}^r \\ t_{p,n}^r - \psi_{p,n}^r, & \text{otherwise} \end{cases} \tag{26a}$$

$$V^{2N,l} = \max_{1 \leq n \leq N}\left(x_{n,2}^{2N,l} - \psi_{p,n}^1 ; x_{n,4}^{2N,l} - \psi_{p,n}^2\right) \tag{26b}$$

In the analized problem can be distinguished two procedures of the states generation:

- - procedure I for the object, which is given to the system,
- - procedure II for all objects , which are take out from the system.

<u>Procedure I</u> (for the object, which is given to the system):

$$\sum_{i=1}^{i=N} x_{i,1}^{l,\eta-1} = 0 \tag{27}$$

If the buffer store is full, than the object should be removing. To the buffer store can be displacement of the object under condition, that his delivered time is not early as the displacement time from the buffer store. The object can be have the forced outage in the time, if in the buffer store are many objects. IIn this situation the object waiting before the subsystem. In the chronological order the object can not waiting.

A. The criterion of the forced outage: $b^{\eta\text{-}1\lambda}(t) < b - 1$

Let us assume, that (b-1) is the number of the objects in the buffer store in the time t.

If the last event was displacement of the object from the buffer store, than for the chronological order can be:

- no generate of the non-perspectivenes states,
- no generate of the states, which are may be optimal,
- generate all states.

From this, <u>the procedure of the states generation</u> are given in the form:

$$\underset{n}{\forall} \quad \underset{\mu}{\forall} \quad \underset{\nu}{\forall} \quad \left(x_{n,1}^{\eta\text{-}1\lambda} = 0\right) \wedge \left(\mu_{p,n}^{1} = 1\right) \wedge \left(b^{\eta\text{-}1\lambda}(t) < b\text{-}1\right) \wedge \left(t \geq \left|c^{\eta\text{-}1\lambda}\right|\right) \wedge$$

$$\wedge\left[\left(\gamma_{i,n}^{1} = 1\right) \Rightarrow \left(x_{\nu,1}^{\eta\text{-}1\lambda} > 0\right)\right] \Rightarrow \left(X^{\eta,\lambda} = X^{\eta\text{-}1\lambda} + \Delta X\right) \tag{28}$$

The elements of the matrix $\Delta \underline{X}$ are given in the form:

$$\Delta x_{i,1} = \begin{cases} \mu, & \text{if } i = n, \\ 0, & \text{otherwise} \end{cases} \tag{29a}$$

$$\Delta x_{i,2} = \begin{cases} t_{\mu,n}^{1}, & \text{if } i = n, \\ 0, & \text{otherwise} \end{cases} \tag{29b}$$

$$\Delta X_{i,3} = \Delta X_{i,4} = 0 \tag{29c}$$

The object can waiting on account of the technology, but can not waiting on accont of the chronological order:

$$t_{p,n}^{1} = \vartheta_{p,n}^{1} + \max\left(\varphi_{p,n}^{1}; T_{p,n}^{\eta\text{-}1\lambda} + \tau_{k,n}^{1,\mu}; T_{p,\gamma_n}^{\eta\text{-}1\lambda}\right) \tag{30}$$

where $T_{1,\gamma_n}^{\eta\text{-}1\lambda}$ is the ending time all admissible predecessor direct:

$$T_{p,\gamma_n}^{\eta\text{-}1\lambda} = \max_{\omega_i \in \alpha_{1,\mu}^{\eta\text{-}1}} x_{i,2}^{\eta\text{-}1\lambda} \tag{31}$$

$$\underset{i}{\forall} \quad \left(x_{i,2}^{\eta\text{-}1\lambda} = \mu\right) \Rightarrow \left(\omega_i \in \alpha_{1,\mu}^{\eta\text{-}1,\lambda}\right) \tag{32}$$

$$T_{1,\gamma_n}^{\eta\text{-}1\lambda} = \max_{\omega_i \in \Gamma_n^1} x_{i,2}^{\eta\text{-}1\lambda} \tag{33}$$

$$\underset{i}{\forall} \quad \left(\gamma_{i,n} = 1\right) \Rightarrow \left(\omega_i \in \Gamma_n^1\right) \tag{34}$$

$$k = \begin{cases} \chi_p^1, & T_{b,n}^{\eta\text{-}1\lambda} = 0 \\ j, & \left(T_{p,n}^{\eta\text{-}1\lambda} = x_{j,2}^{\eta\text{-}1\lambda}\right) \wedge \left(x_{j,1}^{\eta\text{-}1\lambda} = \mu\right) \end{cases} \tag{35}$$

B. The existing interlocking in the buffer store

We shall assume, that in the recording time of the event: $b^{\eta-1,\lambda}(t) = b - 1$

The procedure of the states generation is given in the form:

$$\forall_{n} \forall_{\mu} \forall_{\nu} \left(x_{n,1}^{\eta-1,\lambda}=0\right)\wedge\left(\mu_{p,n}^{1}=1\right)\wedge\left(b^{\eta-1,\lambda}\left(\left|c^{\eta-1,\lambda}\right|\right)=b-1\right)\wedge\left(c^{\eta-1,\lambda}<0\right)\wedge$$

$$\wedge\left[\left(\gamma_{i,n}^{1}=1\right)\Rightarrow\left(x_{\nu,1}^{\eta-1,\lambda}>0\right)\right]\Rightarrow\left(X^{\eta,\lambda}=X^{\eta-1,\lambda}+\Delta X\right) \tag{36}$$

The elements of the matrix $\Delta \underline{X}$ are given in the form:

$$\Delta x_{i,1}=\begin{cases}\mu, & \text{if } i=n,\\ 0, & \text{otherwise}\end{cases} \tag{36a}$$

$$\Delta x_{i,2}=\begin{cases}t_{\mu,n}^{1}, & \text{if } i=n,\\ 0, & \text{otherwise}\end{cases} \tag{36b}$$

$$\Delta X_{i,3}=\Delta X_{i,4}=0 \tag{36c}$$

If $t_{\mu,n}^{1}<c^{\eta-1,\lambda}$ the object can not input to the buffer store, but can input in the time $C^{\eta-1,\lambda}$.

<u>Procedure II</u> (for all objects , which are take out from the system):

$$\forall_{1\le i\le N}\left(x_{i,1}^{1,\eta-1}>0\right) \tag{37}$$

$$\left|C^{\eta-1,\lambda}\right|\le\varphi_{p,n}^{2} \tag{38}$$

The procedure of the states generation is given in the form:

$$\forall_{n} \forall_{p} \forall_{\nu} \left(x_{n,1}^{\eta-1,\lambda}>0\right)\wedge\left(x_{n,3}^{\eta-1,\lambda}=0\right)\wedge\left(m_{p,n}^{1}=1\right)\wedge\left(\left|c^{\eta-1,\lambda}\right|\le t_{m,n}^{2}-\vartheta_{m,n}^{2}\right)\wedge$$

$$\wedge\left[\left(\gamma_{\nu,n}^{2}=1\right)\Rightarrow\left(x_{n,1}^{\eta-1,\lambda}>0\right)\right]\Rightarrow\left(X^{\eta,l}=X^{\eta-1,l}+\Delta X\right) \tag{39}$$

The elements of the matrix $\Delta \underline{X}$ are given in the form:

$$\Delta x_{i,1}=\Delta x_{i,2}=0 \tag{39a}$$

$$\Delta x_{i,3}=\begin{cases}m, & \text{if the work task } \omega_n \text{ is obtained on the aggregate } a_{p,\lambda}\\ 0, & \text{otherwise}\end{cases} \tag{39b}$$

$$\Delta x_{i,4}=\begin{cases}t_{p,n}^{2}, & \text{if } \Delta x_{i,3}=m,\\ 0, & \text{otherwise}\end{cases} \tag{39c}$$

The ending time of the maintenance:

$$t_{p,n}^{2}=\vartheta_{p,n}^{2}+\max\left(\psi_{p,n}^{2};T_{2,p}^{\eta-1,\lambda}+\tau_{k,n}^{2,\mu};x_{n,2}^{\eta-1,\lambda};T_{2,\gamma_n}^{\eta-1,\lambda}\right) \tag{40}$$

$$T_{2,p}^{\eta-1,\lambda}=\max_{\omega_i\in\alpha_{2,p}^{\eta-1,\lambda}} x_{i,4}^{\eta-1,\lambda} \tag{40a}$$

$$\forall_{i}\left(x_{i,2}^{\eta-1,\lambda}=b\right)\Rightarrow\left(\omega_i\in\alpha_{2,\mu}^{\eta-1,\lambda}\right) \tag{40b}$$

$$T_{2,\gamma_n}^{\eta-1,\lambda}=\max_{\omega_i\in\Gamma_n^{2}} x_{i,4}^{\eta-1,\lambda} \tag{40c}$$

$$\forall_{n}\left(\gamma_{i,n}^{2}=1\right)\Rightarrow\left(\omega_i\in\Gamma_n^{2}\right) \tag{40d}$$

$$k = \begin{cases} \chi_p^2, & T_{2,p}^{\eta-1,\lambda} = 0 \\ j, & \left(T_{2,p}^{\eta-1,\lambda} = x_{j,4}^{\eta-1,\lambda} > 0\right) \wedge \left(x_{j,3}^{\eta-1,\lambda} = p\right) \end{cases} \tag{40e}$$

$$C^{\eta,\lambda} = \begin{cases} +t_{\mu,n}^{1}, & \text{if the task work } \omega_n \text{ is obtained on the aggregate } a_{b,1} \\ -t_{\mu,n}^{1}, & \text{if the work task } \omega_n \text{ is obtained on the aggregate } a_{b,2} \end{cases} \tag{41}$$

$$b^{\eta,\lambda} = \begin{cases} b^{\eta-1,\lambda} + 1, & \text{if } c^{\eta,\lambda} > 0, \\ b^{\eta-1,\lambda} - 1 & \text{if } c^{\eta,\lambda} < 0 \end{cases} \tag{42}$$

3. The elimination of the states

The purpose of the states elimination is disregard of the states, which are can not provided to acceptable solution for the determination of the bounds.

If the time to the making of the eliminations procedures is smoler as the possible to the generation of the states, which are can be eliminated, than the elimination procedure is the accelerating of the algorithm realization.

For the elimination of the non-perspectivenes states are given the matrix:

$$B_r^{\lambda,\eta} = \left[b_{r,i,p}^{\lambda,\eta}\right] \tag{43}$$

where: $b_{r,i,p}^{\lambda,\eta}$ - the set of the number work taskes, which are in the subsystem in the state $X^{\lambda,\eta}$.

Thay are calculating as follows:

$$b_{1,i,\mu}^{\lambda,\eta} = \begin{cases} 1, & \text{if } \left(u_{1,\mu,n} = 1\right) \wedge \left(\xi_n \le F_{1,\mu}^{\lambda,\eta}\right) \wedge \left(t_{1,i}^{*} \le \xi_i\right) \\ 0, & \text{in a contrary case} \end{cases} \tag{44}$$

The time $t_{1,i}^{*}$ is calculated from the equation:

$$t_{1,i}^{*} = \min \left(F_{2,p}^{\lambda,\eta} + \vartheta_{p,n}^{2}\right) \tag{44a}$$

and $$\forall_{m} \quad \left(u_{p,i}^{2} = 1\right) \wedge \left(F_{1,\mu}^{\lambda,\eta} + \vartheta_{\mu,1}^{1} \le F_{2,p}^{\lambda,\eta}\right) \tag{44b}$$

$$b_{2,p,1}^{\lambda,\eta} = \begin{cases} 1, & \text{if } \left(u_{p,i}^{2} = 1\right) \wedge \left(x_{2,i}^{\lambda,\eta} \le F_{2,p}^{\lambda,\eta}\right) \wedge \left(t_{2,i}^{*} \le \xi_i\right) \\ 0, & \text{otherwise} \end{cases} \tag{44c}$$

$$b_{2,p,1}^{\lambda,\eta} = \begin{cases} 1, & \text{if } \left(u_{p,i}^{2} = 1\right) \wedge \left(x_{2,i}^{\lambda,\eta} \le F_{2,p}^{\lambda,\eta}\right) \wedge \left(t_{2,i}^{*} \le \xi_i\right) \\ 0, & \text{otherwise} \end{cases} \tag{44d}$$

where: $$t_{2,i}^{*} = t_{i}^{*} \tag{44e}$$

The rows of the matrix $B_r^{\lambda,\eta}$ are non realized the work taskes, the columns are some aggregates of the subsystem. If in the matrix $B_1^{\lambda,\eta}$ is existing the row, in which all elements are zero, then can not realized the work taskes with the number of this row. The controlling of the matrix $B_1^{\lambda,\eta}$. If in the rows of the matrix $B_1^{\lambda,\eta}$ are existing the elements non-zero, than the matrix $B_2^{\lambda,\eta}$ is controlling. The state is staying, if in the matrix $B_1^{\lambda,\eta}$ and $B_2^{\lambda,\eta}$ is existing more or one element one.

To the elimination of the non-perspectivenes states in the regeneration system with the cenral buffer store are using the rules: the probing rule and the predominate rule. The deplete rule for this system is not existing.

The deplete rule:

From two states: X^{η,l_1} and X^{η,l_2}, for which are performed the conditions:

$$\left(x_{n,1}^{\eta,l_1}=0\right)\Rightarrow\left(\omega_n\in\Omega_1^{\eta,l}\right) \tag{45}$$

$$\left[\left(x_{n,1}^{\eta,l}>0\right)\wedge\left(x_{n,3}^{\eta,l}=0\right)\right]\Rightarrow\left(\omega_n\in\Omega_2^{\eta,l}\right) \tag{46}$$

and the relation:

$$\underset{n}{\forall}\ \underset{i}{\forall}\ \left[\left(\omega_n\in\Omega_1^{\eta,l_1}\right)\Rightarrow\left(\omega_n\in\Omega_1^{\eta,l_2}\right)\right]\wedge\left[\left(\omega_i\in\Omega_2^{\eta,l_1}\right)\Rightarrow\left(\omega_i\in\Omega_2^{\eta,l_2}\right)\right]\wedge$$

$$\wedge\ \left(\varphi_{p,n}^{\eta,l_1}\le\varphi_{p,n}^{\eta,l_2}\right)\wedge\left(\varphi_{p,i}^{\eta,l_1}\le\varphi_{p,i}^{\eta,l_2}\right)\wedge\left(V^{\eta,l_1}\le V^{\eta,l_2}\right) \tag{47}$$

the state X^{η,l_1} is dominated under the state X^{η,l_2}.

3. CONCLUSIONS

To solve the regeneration processs scheduling the multistage programming method is used. The problem is analized with the determined bounds. The elimination of the bounds will in the consequence changing of the algorithm and of the maximization the task work realization criterion. The presented problem of the regeneration process scheduling sould be continued in the longer development works in the computers testes range.

REFERENCES

[1] Rasztabiga D, Marecki F.: Modelling of a Rolling - Mill Line. International Conference on COMPUTER INTEGRATED MANUFACTURING ZN Pol. Śl., Mechanika z. 108, Gliwice 1992, pp. 323-334.

[2] Marecki F.: Zielińska - Król E.: Model matematyczny i algorytm harmonogramowania regeneracji walców. ZN Pol. Śl. Automatyka z 64, Gliwice 1982, pp. 95-107 (polish).

[3] Rasztabiga D.: Sterowanie operatywne procesem walcowania ZN Pol. Śl. Automatyka z 110, Gliwice 1992, pp. 109-124 (polish).

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