OPTIMIZATION OF BAR CUTTING PROCESS

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Abstract: Among the authors’ interests we enumerate integrated Kanban processes, fields in which the authors published a few papers. An important technical-economic issue in manufacturing heat-insulation materials is the optimization of the cutting process of expensive bars using numerical-controlled cutting machines, in view of reducing the losses of bars ends. Apparently simply as phenomenon, the optimization of bars’ precise cutting process, integrated in Kanban processes, is complex but increases the efficiency of the cutting process by reducing the material losses. The paper presents the diagram of organizing the cutting department, of optimizing the process and algorithm of department operation.

Key words: cutting process, optimization

1. OBJECT OF THE PAPER

Following up the papers [1, 2, 3, 7] elaborated in the last four years by the authors of the present paper, the goal is to develop the physical and functional model of bars cutting department. At the basis of these developments lies paper [6]. The main objective of the paper is the elaboration of the optimization model for bars cutting process, integrated in a Kanban process.

2. CURRENT STATE OF THE PROBLEM

The authors of papers [1, 2, 6, 7] analyzed the current manufacturing process (reference year 2003) of heat-insulation carpentry in a Romanian factory and forwarded solutions for factory reorganization on basis of integrated Kanban processes; these solutions have been applied since 2005 and the forward-looking models developed in papers [3, 4, 5] proved to be viable ever since 2006.

The problem dealt with in this paper has been approached, worked out and applied in real industrial environment since 2005.

The paper aims at optimizing the cutting process of PVC bars in manufacturing heat-insulation carpentry.

3. COMPOSING THE CUTTING STATION

Bars cutting represent the first operation in the flow of material processing, being located on the flow input (upstream)

Taking into account the fact that the cutting process is conducted on three different types of materials and bars profiles - PVC, OL and Al, on three different machines, they will form the cutting station, placed on input (upstream) in the manufacturing flow. The number of cutting machines and their automation degree results from Fig. 1. Consequently, the cutting station will be made up of three independent work sites (PVC, OL, Al), which work in parallel, each being composed of: PLPVC (2 machines), PLOL (2 machines) and PLAl (1 machine).

The material couplings of the cutting station are: on the input - with the following work sites (insertion, tracing, assembling)

The structure of the material processing flow through integrated Kanban processes will be ordered in parallel – series (mixed type), according to the material storage model [7, 1, 2] where StD is the cutting station; (PL(j+1), PLk, PL(j-1)) are the work sites for cutting bars made of PVC, OL and Al, each including the number of machines previously stated; PL(j,1) does not exist; DzM exists as materials warehouse for the safety stock (SS) in line, which substitutes PL(j,1); mobile ST(i) and ST(d) exist for the stock on flow (SF); P = Pr and Pd = Pr of StD exist as well. Consequently, the graphical model of particularized integrated KANBAN process will be the one in [7, 1, 2], and the diagram of ordering and organizing the cutting technological flow is presented in Fig. 1.

In Fig. 1, the following notations were used: MD – cutting machine; PVC, OL, Al - PVC, steel, and aluminum; AL - supply; PL(1-S) - insertion-welding work site - PLTs - tracing work site; R - fixed creels; CRM - mobile trolley creel; CB - bar end; Pl,d - loading - unloading site; TPRT - return conveyance.

The cutting station is provided with three distinct categories of cutting machines: two for PVC, two for steel and one for aluminum.

The materials warehouse is equipped with one DzM for all types of materials and with two fixed creels, one for each optimized bar end (RCB) made of PVC and Al, one for Al; three distinct material flows emerge from DzM - one for PVC, the second for steel and the third for aluminum. The aluminum processing flow is independent, and the other two are dependent and concurrent on the same welding and insertion work site.

The functions Lv / Tp and AL in the diagram presented in Fig. 1 are assured by mobile storing devices on flow ST (Lv / Tp, AL), materialized through SbTpv, k = PVC, OL, Al, composed of SbTpv = {CRMpv, k = 1 \leq PVC, k = 2 \leq OL, k = 3 \leq Al; i = 1 \leq loading, delivery, conveyance, supply, i = 2 \leq r recycling the bar ends in/from fixed creels for bar ends made of PVC and Al, i
4. OPTIMIZING THE BARS CUTTING PROCESS

The bars cutting process, from systemic point of view, must be regarded at global level, as a whole, and evaluated through the totality of directly and indirectly productive, material and information activities that constitute the whole cutting process. Consequently, the optimization of bars cutting has to be conducted on the whole cutting process not on isolated stages.

The aim of optimizing the cutting process is to minimize the losses from each k bar (k = PVC, OL, Al), as well as from each bar with similar profile, taken separately. The notations used for this goal are: Ln - nominal length of the cut bar, necessary in subsequent material processing, variable with the product Rk; Lbi - length of initial, complete bar of 6 m; LCb - length of the bar end left after the first cutting, less than 6 m, recycled the first time in RCBk; L’Cb - length of bar end left after the second and subsequent cutting, less than 6 m, recycled the second and subsequent time in RCBk; x - current bar end. The following cases may occur during processing: x ≥ Ln, x ≤ Ln, x = Lcb - Ln, x = L’cb - Ln; p0 - admitted loss of bar end, imposed through the management decision.

The diagram of optimizing the bars cutting process is presented in Fig. 2 where: Cji is the current ij component of the manufacturing system; PSij - software product necessary in the optimization process; ECN - numerical control equipment of MDk; CP - comparing element in the optimization process; AF - system display; RaM - material ramification.

At the basis of optimization process lie the lists with stock of complete bars Ln = 6 m in PS5 – Y5, existent in DzM = C12 – Y12, updated through ApM = iFm – x121 and x52 and re-updated through x51 and the stock of bars ends LCb < 6 m existent in RCBk – C13 received from MDk – C15 through CRM2 – C19, updated through x13 and re-updated thorough x61 and x62 on PS6 – Y6. These lists are found on PS3 and PS4 basis, resulted from PROIECT – C1 – Y11P.

The optimization process has two components: automated and material component.

Compotted component: The computed component contributes to the following decisions:

1) If Lcb < Ln then PS9 emits the signal Y91 = x62 on PS6 and this is retained on the list;

2) If Lcb = Ln then x = p0 = 0 and PS9 emits the signal Y92 = x132 on C13 = RCB and the bar is extracted from RCBk and is transferred to the container CRM1 = C14, Y13 = X142;

3) If Lcb > Ln then x > p0 resulting two other decisions:

a) If Lcb = Ln + x and x ≤ p0 ≠ 0, then PS10 emits the signal Y101 = x131 on C13 = RCBk and the bar is extracted from RCBk and it is transferred to container CRM1 = C14, Y13 = X142;

b) If Lcb = Ln + x, x = L’cb > p0, then PS10 emits the signal Y101 = x131 on C13 = RCBk and the bar is extracted from RCBk and is transferred to container CRM1 = C14, Y13 = X142;

4) If Ln ≥ Lcb then x ≥ p0, resulting two other decisions:
Fig. 2. The diagram of optimizing the bar cutting process.

a) $L_{bi} = L_n$ or $\Sigma L_n$, when $x = p_a = 0$, then PS10 emits the signal $Y_{102} = x_{122}$ on $C_{12} = DzM$ and the bar is extracted from $DzM$ and is transferred to container $CRM1 = C_{14}$, $Y_{12} = X_{141}$.

b) $L_{bi} = L_n + x$ when $x = L'_{CB} > p_a$, then PS10 emits the signal $Y_{102} = x_{122}$ on $C_{12} = DzM$ and the bar is extracted from $DzM$ and is transferred to container $CRM1 = C_{14}$, $Y_{12} = X_{141}$.

The company's policy imposes $L'_{CB}$ = variable according to stock volume on CB in RCB, $L'_{CB} \in (L'_{CB} = 300 \text{ mm}, L'_{CB} = 350 \text{ mm}, L'_{CB} = 400 \text{ mm})$.

The stage of elaborating the CNC cutting program belongs to the automated component and consists of the following automated-related activities:

1) On the basis of designing drawings of the project $C1 - Y12$, at the programming point $C7 - X7$ there is developed the NC cutting program $PS8 = x_{8} = Y_{7}$;

2) The NC cutting program is transmitted $ECN - C11 - x_{11} = Y_{11}$ which transmits the information $L_n = Y_{11}$ in $CP - C16$, with the role of emitting the message $x_{153} = Y_{161}$ to $MDk - C15$ and of fulfilling the comparison $x = (L_{bi}, L'_{CB}) = L_n = Y_{162}$ in $AF - C17$, useful $OpU$ for marking the left bar end, through labeling.

Material component: The material component contributes to the following decisions and activities that are directly and indirectly productive:

1) The complete bars ($bi$) are to be found in containers arranged on types of materials (PVC, OL or Al) and codified on profiles, in DzM. The bar ends (CB) are arranged in various compartments of RCBk, on types of materials and profiles and can be identified through:

   - department label specific to shelf expressing the material's code (PVC, OL, Al) and profile; the department label is fixed;

   - bar label, expressing the material's code, profile and length of bar end ($L'_{CB}$); this is conveyed by each bar on the trajectory of its movement in the processing flow, it is of “barcode” type, it is read with an opto - electronic device (scanner), in both $C13 - RCBk$ and $C18 - RaM$.

   The bar label changes together with the change of the bar length, ($L_{CB}, L'_{CB}$) = var after cutting in $C15 = MDk$; the bar level turns into $C18 - RaM$.

2) By displaying $C22 - AF$, the human operator (OpU) receives the identification and selection messages of a number of bars of similar type. Through message $x_{122}$, OpU selects and extracts from $DzM$ a number of complete bars -- $Y_{12}$ and transfer them to $CRM1 - X_{141}$; through messages $x_{131}$ and $x_{132}$, OpU selects and extracts from $RCBk$ the required number of bar ends of each type -- $Y_{13}$ and transfer them to $CRM1 - X_{142}$.

3) $CRM1$ is transferred/received from $MDk$, $Y_{141}, Y_{142} / x_{151}, x_{152}$.

4) According to messages displayed in $C23 - AF$, OpU supply $MDk$ with the required bar. $MDk$ supply is done manually after identification and selection, by reading the bar label with the optical device, which emits signals in $C16 = CP$, ($x_{161} U x_{162}$).
5) MDk fulfills the material processing through the cutting process by the intermediary of CI1 – ECN, according to program Y8 & Y11 & (Y161 = x153), delivering on output Y15 – bars with nominal length $L_{bi} = \sum_{i} Y \in Y_{15}$, var, using signals x153 = Y161.

6) In the display C17 – AF, OpU reads visually Y15 = $L_{bi} = \sum_{i} x_{171}$ and Y162 = $x = (L_{bi}, L_{cb}) - Ln$ = Y172 and through the optic device it emits: signals Y171 = x51 expressing the integral consumption of the complete bar $L_{bi} = \sum_{i} Ln, x \leq p_{a}$, or on the partial one $x_{61}, L_{bi} > \sum_{i} Ln, x = L_{cb} > p_{a}$ for updating PS5; the signal Y172 = x51 expressing the integral consumption of the bar end $L_{cb} = \sum_{i} Ln, x \leq p_{a}$ or partial $x = L_{cb} > p_{a}$ for re-updating PS6.

7) In C18 = RaM, OpU handles bars with Ln in CRMk = C20 which will be sent on the upstream material flow Y20; $x_{20} = Y_{181} = x_{181} = Y_{171}$; the tailings $x \leq p_{a}$ to wastes $C21 - x_{21} = Y_{182}$ and newly resulted bar ends $L_{cb} = x > p_{a}$ will be handles in C19 = CRM2 for recycling in RCBk – C13, that is $x_{133} = Y_{19} = Y_{183} = x_{192} = Y_{172}$.

All he decisions and activities previously mentioned are expressed through the following operation algorithm of the cutting station with optimized processing, run by a numerical control-based program.

Initially fulfilled conditions: (Y11P, Y12P) = 1, (Y3, Y4, Y5, Y6) = 1, (Y7, Y11 = Ln) = 1, $x_{121} = i_{3m} = 1$.

Operation algorithm

**STEP 1** = S1 IF $Y6$ THEN $x9 (L_{cb} \neq Ln)$

**STEP 2** IF $Y91 (L_{cb} < Ln)$ THEN ($x9$ & GO ON S3)

**STEP 3** IF $Y92 (L_{cb} = Ln, x < p_{a})$ THEN (x132 & SELECT LABEL KTL_{cb}) ELSE GO ON S5 where: K – material (PVC, OL, Al); T – type (profile); $L_{cb}$ – length (length of bar end - $L_{cb}$)

**STEP 4** SELECT LABEL KTL_{cb} THEN EXTRACT FROM RCBk AND TRANSFER CRM1 – Y13

**STEP 5** IF $Y101 (L_{cb} = Ln + x, x \leq p_{a} = 0, L_{cb} = Ln + x, x = L_{cb} > p_{a})$ THEN (x131 & SELECT LABEL KTL_{cb}) ELSE GO ON S7

**STEP 6** IF SELECT LABEL KTL_{cb} REPEAT S4

**STEP 7** IF $Y5$ THEN $x10 (L_{bi} = 6 ml)$

**STEP 8** IF $Y102 (L_{bi} \geq Ln; L_{bi} = \sum Ln, x = p_{a} = 0; L_{bi} = Ln + x, x = L_{cb} > p_{a})$ THEN (x122 & SELECT LABEL KTL_{cb})

**STEP 9** IF SELECT LABEL KTL_{bi} THEN EXTRACT FROM Dz2M AND TRANSFER CRM1 – Y12

**STEP 10** REPEAT S1 … S9 AS FAR AS TO EXHAUST (PS6 & PS5)

**STEP 11** IF (Y13 & Y12) THEN (Y141 & Y142) – CRM1 GO TO MDK (x151 & x152)

**STEP 12** IF (x151 & x152) THEN IDENTIFY LABEL (KTL_{cb} OR KTL_{bi}) FROM CRM1 AND TO FEED MDK (x161 & x162)

**STEP 13** IF (x161 & x162) THEN MATERIAL PROCESSING MDK (Y11 = Ln & (x161 & x162) => $x_{153} = Y_{161}$)

14) IF $x_{153}$ THEN (Y15 = $L_{bi}$) & (Y162 = $x = (L_{bi}, L_{cb}) - Ln$)

**STEP 15** IF ((Y15 = $L_{bi}$) & (Y162 = $x = (L_{bi}, L_{cb}) - Ln$) = $x_{171}$)) THEN IDENTIFY ((Y171 = $L_{bi} = \sum Ln, x \leq p_{a}$)

OR ((Y171 = $L_{bi} > Ln, x > p_{a}$)) OR ((Y172 = $L_{cb} = Ln, x = p_{a} = 0$) OR (Y172 = $L_{cb} > Ln, x = L_{cb} > p_{a}$))

S16 IF (Y171 & Y172) REPEAT S12 … S15 AS FAR AS TO EXHAUST CRM1;

S17 IF ((Y171 = x181) & (Y172 = x182)) THEN IDENTIFY AND SELECT AND MARK LABEL (KTL_{cb} &)

S18 IF Y181 = Ln THEN GO TO CRM3 – x20 ELSE Y182 = $x \leq p_{a}$ GO TO x21 ELSE Y183 = $L_{cb}$ GO TO CRM2;

S19 IF Y183 = x19 THEN CRM2 GO TO RCBk – Y19 = $x_{133}$;

S17(1) IF Y171 THEN x51; S17(2) IF Y172 THEN x61.

5. CONCLUSIONS

The optimization process resulted in a soft product made up of a NC program and an optimization program, which was designed and applied and which operates in a real manufacturing environment. This program allows the minimization of material losses in the consumption of profiles made of expensive materials, reducing the losses, which condition the Kanban Process.

REFERENCES


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