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THROUGHPUT FOR STEEL PIPES MANUFACTURING PROCESS DESIGN

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Conventional approach to pipe manufacturing process design is using capacity to satisfy maximal load for each process. In the new approach, throughput is suggested as a basic determinant aiming at finding dynamic balance among following and previous process phases. Throughput is defined by the interval of time between product exiting from the preceding process phase and its entry to the next one. Interval of time for the product delivery from the preceding phase must be less or equal as the amount of time necessary for activating the next phase. Knowing the performances of the next phase one can impact to the characteristics of the preceding phase. Throughput can be also used as a more precise way for observed process productivity measurement. Such approach is suggested and for other complex technological processes.

Key words: technological process, steel pipe manufacturing, throughput, capacity

Propusnost kod projektiranja procesa izrade čeličnih cijevi. Konvencionalni pristup projektiranju procesa izrade cijevi koristi kapacitet kako bi se zadovoljilo maksimalno opterećenje u svakom trenutku procesa. U novom se pristupu kao temeljna odrednica predlaže propusnost, koja teži iznalaženju dinamičke ravnoteže narednih i prethodnih faza procesa. Propusnost se definira međuvremenima izlaza proizvoda iz jedne faze procesa i ulaska u narednu, gdje međuvrijeme isporuke proizvoda iz promatrane faze, mora biti manje ili jednako vremenu potrebnom za aktiviranje naredne faze. Tako je moguće, poznavajući performanse narednog procesa, utjecati na karakteristike onog promatranog. Propusnost se koristi i kao precizniji način mjerenja učinkovitosti promatranog procesa. Pristup se može koristiti i za druge složene tehnološke procese.

Ključne riječi: tehnološki proces, izrada čeličnih cijevi, propusnost, kapacitet

INTRODUCTION

To increase productivity, new automatic production lines are introduced driven by adequate computer hardware and software. While determining production process characteristics for building complex product such as steel vessel, special consideration is given to dimensioning and defining capacity of production equipment and working places. Process characteristics should accomplish building and outfitting dynamics of such product, in mode not to result in sub capacity or overcapacity of the production process.

In case of process overcapacity, manufacturing time will be prolonged or temporary production stoppage will occur. In case of process sub capacity, production line will function within normal circumstances with increased degree of spare capacity, while certain process segments will be idle. Modern production line should have such technical and technological characteristics as to insure disposition of required resources and to enable continuous production.

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Production line has frequently higher capacity than needed. To avoid such case, important is to know requirements dynamics, and on that bases to determine characteristic dimensions and manageability of production process. Process dynamic estimation can be achieved in several ways [1]:

- by data analysis for previous time period as a base for calculation and forecasting capacity of new production line.
- by date analysis similar production program, for vessel types that are planned to be built within the system in longer time period.

NEW APPROACH TO PRODUCTION PROCESS DESIGN

Conventional approach to production process design [2] is based upon accomplishing total capacity of the production process while not sufficiently taking into consideration of sub processes and their interactive tact synchronizations. As a consequence, the need for buffer space of intermediate products among particular production process phases is noted. Also, idleness among particular production phases is noted. It is happening within technological processes with higher participation of hand made and human resources for manufacturing and metal forming [3].

For modern production line designs a new approach is required, because in conventional mode by using capacity, as basic determinant, production process efficiency cannot be expressed precisely enough. Production process efficiency, except through capacity, can be measured by tact's synchronizations of following and observed manufacturing phase in relation to observed process. Therefore here, throughput is introduced, as a new way of measuring production process efficiency and which is also use as basis for modern pipe production line design.

DETERMINANTS FOR PRODUCTION PROCESS THROUGHPUT DEFINITION

To define production process throughput, initially, it is required to determine manufacturing time and queuing intermediate times related to following process realization. Precise determination of process activity duration is conditioned by exact description of predicted procedures for its execution. Contemporarily, one should take into consideration working personal qualifications, machines and other production means, capacities and characteristics, as well as working modes (overtime work, work in shifts, using cooperation work forces and means, etc.). Further it is necessary to ensure continues acquiring of needed input materials, and continues overtaking of produced interim products, or completed products within interim storage spaces of following process, or within storage space of completed products [4]. Production process throughput is defined by queuing time interval for completion of following process Δt_i, defined as difference of the time of following process t_{i+1} and observed manufacturing process, t_i i.e.:

$$\Delta t_i = t_{i+1} - t_i . \qquad (1)$$

If the queuing time interval of the following process Δt_i equals zero, production line is synchronized in tact's. Everything produced within i process, is continuously entering to i+1 process, without necessities to generate process storages and product buffer spaces. If $\Delta t_i < 0$, it means that i+1 process is sub capacitated, while production lines operates discontinuously without process storages and product buffer spaces, and i+1 process is waiting upon i process execution. If $\Delta t_i > 0$ then i process is producing certain quantity of process storages for the needs of following manufacturing process executing, i.e. the interim products of i process are queuing within buffer space, waiting for further manufacturing to i+1 process.

Process line throughput is based upon knowledge about interim queuing times between following and observed manufacturing processes measured the whole process line. Maximal queuing time interval is defining the critical process line throughput position,

$$\Delta t_{i\,max} = \max (\mid t_{i+1} - t_i \mid), \qquad (2)$$

Knowing following process characteristics one can influence on observed process characteristics, while queuing time interval Δt_i should be minimized. It is desirable as to avoid production perturbations and stoppages [5], for each manufacturing process to ensure certain queuing time interval, which is defined as spare time. In that case Δt_i is always positive, while such defined process, as a premise must have adequate buffer space for interim products waiting to be driven towards manufacturing process [6].

If the following process has several entering processes, performing simultaneously throughput, calculation includes that interval of time, which has the longest duration.

Process line throughput as a whole is measured by sum differences of all manufacturing times and some of absolute queuing time intervals and idle times respectively.

If certain processes are performing in parallel or are contemporarily entering towards the following process as a referent one, that process is to be denominated, whose queuing interval of time to perform following process has the longest duration:

$$t_{throughput} = \sum_{i=1}^{n} \max(t_i) - \sum_{i=1}^{n} |\Delta t_i| . \qquad (3)$$

where $i = 1, n$ is number of processes.

As this number being smaller, the smaller is the production line throughput, while queuing time interval for following process execution is higher, such as idle time, respectively. For the ideal case, while production line is operating without spare time or idle time, i.e. while $\sum \max \mid \Delta t_i \mid = 0$, maximal process line throughput is ensured, where:

$$t_{throughput} == \sum_{i=1}^{n} \max(t_i). \qquad (4)$$

Upon production process total duration can be acted by changing manufacturing process duration t_i and by changing following manufacturing process queuing time interval Δt_i. Manufacturing process duration is constant value and depends on process equipment characteristics and on working places, while queuing time interval is variable value depending on technological process organization and complexity of manufactured elements. Production process, which has the longest queuing time interval Δt_i, represents the critical position for production line throughput, based on which remaining production sub processes within the production line are synchronized.

If production process total duration:

$$\sum \max (t_i) + \sum \max \mid \Delta t_i \mid \qquad (5)$$

is not satisfying manufacturing dynamic against planned needs, and also can not be improved by further influence upon queuing time interval Δt_i then process line is sub capacitated. In such case, at working places having longest manufacturing duration, actions are taken towards process equipment and working places productivity improvement, aimed towards manufacturing duration shortening, and also towards increasing throughput and production line productivity, respectively [7].

THROUGHPUT ANALYSIS WITHIN VIRTUAL PIPES MANUFACTURING WORKSHOP DESIGN

Against calculated pipes consumption distribution for particular vessel types [1], 94% from total manufacturing pipes within pipes workshop are between nominal diameters from DN 15 to DN 150, which is driving to conclusion that in this area of pipe manufacturing, the need for virtual pipe workshop exist to operate within automatic or semiautomatic mode. For steel pipes manufacturing of nominal diameters higher than DN 150, whose total share is approximately 6%, it is sufficient for the virtual manufacturing workshop to operate within semiautomatic or handmade mode, respectively. Production process throughput determination is analysed in way of virtual workshop for steel pipes manufacturing, which can operate within three basic modes, i.e., completely automatic, Figure 1, semiautomatic, Figure 2 and hand made Figure 3.

Case 1. Pipes manufacturing in automatic mode for nominal diameters DN65 to 100 mm:

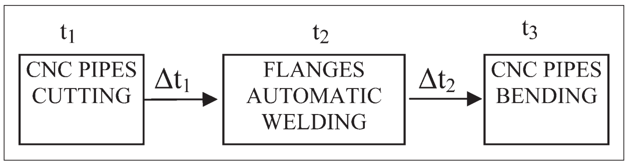

Figure 1. Block diagram of pipes manufacturing in automatic mode

According eqn. (1) queuing time intervals against table 1 are calculated as follows:

$$\Delta t_1 = t_2 - t_1 = 4 - 4 = 0,$$

$$\Delta t_2 = t_3 - t_2 = 4 - 4 = 0.$$

Against eqn. (3) total line throughput for manufacturing of pipes with nominal diameters DN65 to 100 mm:

$$t_{throughput} = (t_1 + t_2 + t_3) - (|\Delta t_1| + |\Delta t_2|)$$
$$= (4 + 4 + 4) - (|0| + |0|) = 16,$$

which means that for such conditions maximal throughput for pipe production line is ensured, Figure1.

Case 2. Pipes manufacturing in automatic mode for nominal diameters DN125 to 150mm:

According eqn. (1) queuing time intervals against table 1 are calculated as follows:

$\Delta t_1 = t_2 - t_1 = 5 - 7 = -2,$

$\Delta t_2 = t_3 - t_2 = 6 - 5 = 1.$

Against eqn. (3) total line throughput for manufacturing of pipes with nominal diameters DN65 to 100 mm equals:

$$t_{throughput} = (t_1+t_2+t_3) - (|\Delta t_1| + |\Delta t_2|)$$
$$= (7 + 5 + 6) - (|-2| + |1|) = 18-3 = 15,$$

which means that for pipes manufacturing of nominal diameters DN 125 to 150 mm within automatic mode, the pipe cutting process is sub capacitated, while process of flanges automatic welding is waiting for processing pipes cutting completion, Figure 1.

If any pipes manufacturing process within performing in particular mode is not executing the whole manu-

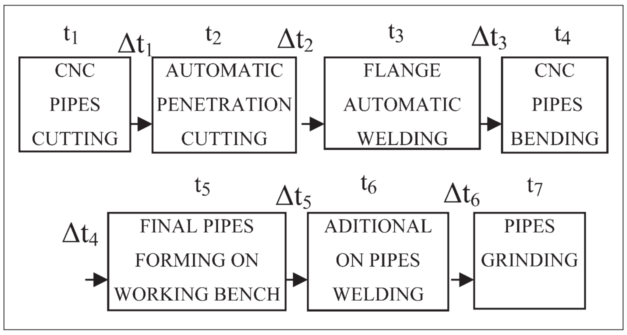

Figure 2. Block diagram of pipes manufacturing in semiautomatic mode

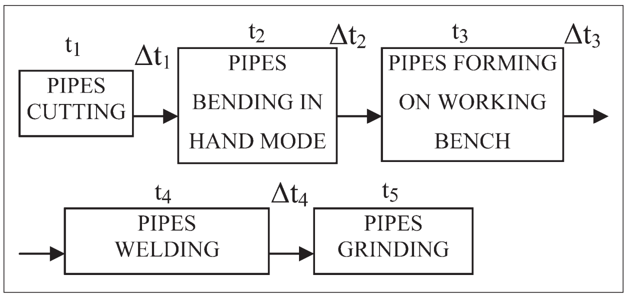

Figure 3. Block diagram of pipes manufacturing in manual mode

facturing process is bypassed. Its manufacturing duration equals zero. The same process is to be performed within the first following pipe manufacturing process. For each of three sighted modes, process throughput has to be determined. The overall efficiency of steel pipes manufacturing workshop, is based on each particular process throughput operating within particular mode.

CONCLUSION

Directions to determination of design characteristics of steel pipes manufacturing workshop are given. Process throughput is analysed, as basic element of the new approach for manufacturing process design, measuring and efficiency definition.

Table 1. **Times for processes of pipes manufacturing in automatic and semiautomatic modes**

DN / mm	CNC PIPES CUTTING	CNC PENETRATION CUTTING	FLANGE AUTOMATIC WELDING	CNC PIPES BENDING	PIPES FORMING ON WORKING BENCHES	PIPES WELDING	PIPES GRINDING
	PROCES TIME DURATION, t_i / min.						
15-50	3	2	3	4	15	7	5
65-100	4	2	4	4	20	15	6
125-150	7	4	5	6	25	20	7
150-200	10	4	7	8	30	40	9
> 200	15	5	9	-	40	80	15

New approach analysis results in more appropriate technological process optimisation, manufacturing process duration shortening and production resources rationalization. Furthermore, through queuing time intervals, bottlenecks can be predicted as well as process activities with spare time. In that manner additional possibilities can be foreseen for process optimisation. The approach can be recommended for other complex technological process designs.

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Note: The responsible translator for Englisch Language is K. Mance, Rijeka, Croatia.