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An analysing of heat treatment process planning

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ABSTRACT

Purpose: Process planning of heat treatment has been investigated. The established approach of heat treating process planning is suitable for effective integration of heat treatment in computer added manufacturing.
Design/methodology/approach: Process plan of heat treating process has been established based on fundamental process planning principals. The heat treatment was treated in the same as other manufacture processes.
Findings: The general approach for process planning of heat treatment processes has been established. Heat treatment processes have to be designed into operations and sub-operations with the same principles that are also valid for other manufacturing processes.
Research limitations/implications: The further research should be focused on development of methods for the better application of achieved results.
Practical implications: This way of heat treatment process planning is more appropriate for integral trends of manufacturing, i.e., with the trend of introducing the modern systems in all parts of industrial manufacturing.
Originality/value: The global approach of process planning of heat treatment processes was established and better unification with other manufacturing processes was achieved.
Keywords: Production planning and control; Heat treatment; Quenching and tempering; Case hardening

1. Introduction

The heat treatment is often constituent part of integral manufacturing but some times without necessary industrial approach [1][2].

In manufacture processes heat treatment operations often are done in separated workshops. The process cycle is broken in this case and a manufacture cycle could be significantly prolonged [3].

Investigations done in a large number of enterprises, suggests that logistic documentation of heat treatment often do not satisfy modern production requests that the distinction and connection between operations have to be clearly defined [4]. Process planning documentations of heat treatment, i.e., operation sheets, are usually without of relevant data, required for modern industrial process management and manufacture integration [5].

Heat treatment documentation is usually essentially different from other manufacturing processes documentation. Differences originate from subjects, form and way of interpretation of manufacturing data. The efficiency of heat treatment process is diminished and particularly, difficulties originate in introduction of computerized manufacturing [6][7].

According to process planning techniques everyone manufacturing process of some product can be divided into an encompassed group of works named operations. Operations have to be continuously performed at one work place. They can be directly managed or controlled by one worker, workers group, or by control unit, device/machine, i.e., by automotive production system [8]. This is fundamental definition of manufacturing operation and must be respected in process planning of heat treatment processes [9][10].

Heat treatment can rarely be composed by one operation. Heat treatment of some product is usually composed by a set of operations. At this situation, for unambiguous definition of an operation set and for setting efficient operations linking the logical groups of works have to be identified and their connections during execution have to be defined [11].

2. Peculiarities of process planning of heat treatment processes

Based on essential microstructure transformations that exist during the heat treatment, heat treating processes can be divided into logical parts. For example, quenching and tempering can be divided into austenitizing, hardening and tempering [12][13].

Traditionally, the group of works on which quenching and tempering is consisted, is often treated as one operation, consisted on three parts, i.e., sub-operations: austenitizing, hardening and tempering. But it can be wrong. The operation has to be defined based on work-place. If the heat treating processes are performed in some separated work-places, (furnaces, bathes, pre- and post-facilities etc.), they had to be grouped into several operations in accordance with number of work-places. If the test or cleaning processes are include in activities of heat treatment personnel, and if they are performed in other manufacture devices, they have to be considerate as pre- or post-operations.

2.1. Quenching and tempering

In the case when the heat treatment process of quenching and tempering is consisted on cleaning, quenching and tempering process, and if that processes are executed in different working places must be designed into separate operations: (1) cleaning, (2) quenching and (2) tempering (Fig. 1, Table 1).

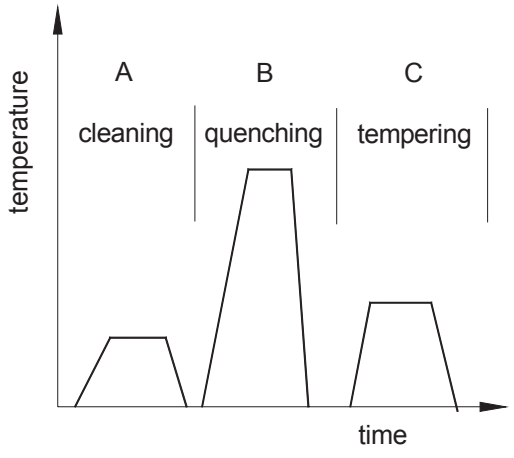

Fig. 1. Diagram of non-automated quenching and tempering

Table 1.
Operations of non-automated quenching and tempering

Operation number	Operation name	Procedure parameters	Work place
XX+1*	Cleaning	$x_{11}, x_{12},\ldots$	A
XX+2	Quenching	$x_{21}, x_{22},\ldots$	B
XX+3	Tempering	$x_{31}, x_{32},\ldots$	C

* XX - previous operation

If the process of cleaning is executed into separate facilities of process of quenching and tempering the heat treatment process of quenching and tempering has to be divided in two operations: (1) cleaning and (2) quenching plus tempering (Fig. 2, Table 2):

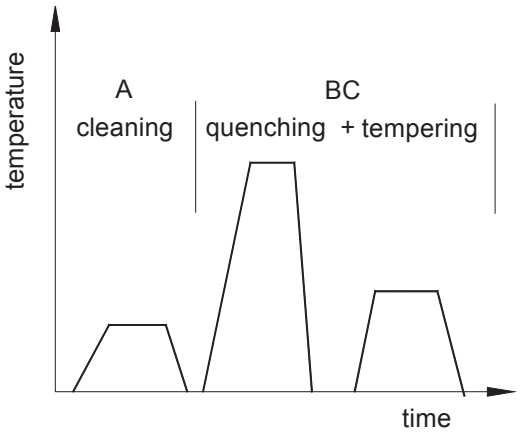

Fig. 2. Diagram of automated quenching and tempering

Table 2.
Operations of automated quenching and tempering

Operation number	Operation name	Procedure parameters	Work place
XX*+1	Cleaning	$x_{11}, x_{12},\ldots$	A
XX+2	Quenching + Tempering	$x_{21}, x_{22},\ldots$	BC

* XX - previous operation

Process planning development trends to integrate manufacture processes. It is leading to the developing of technology equipment on which is possible to complete all manufacture process by only one operation including the heat treatment [14]. There are, for example, manufacture centres with large number of cutting tools including the laser and quenching unit for surface engineering.

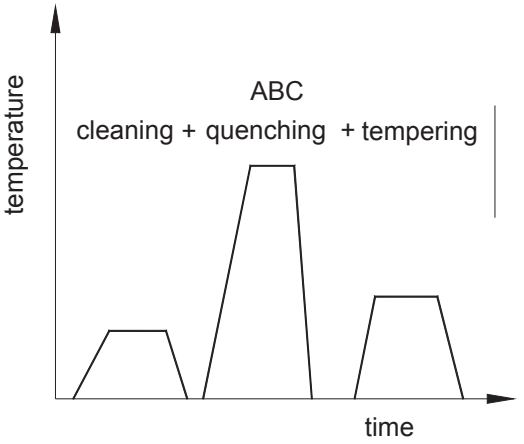

Fig. 3. Diagram of full automated process of quenching and tempering

Manufacture process has only one operation divided on some sub-operations, i.e., holds. Process details and parameters of complete operation have to be defined and put in NC-program. Therefore, if full automated heat treatment process of quenching and tempering is executed in one work place, automated process of quenching and tempering must be structured into one production device, i.e., must be defined by one operation, (Fig. 3, Table 3).

Table 3.
Operations of full automated quenching and tempering

Operation number	Sub-operation number	Sub-operation name	Procedure parameters	Work place
	XX+1.1	Cleaning	x_{11}, x_{12},...	
XX*+1	XX+1.2	Quenching	x_{21}, x_{22},...	ABC
	XX+1.3	Tempering	x_{31}, x_{32},...	

* XX is number of previous operation

2.2. Case hardening

From the heat treatment theory point of view, i.e., on the basis of essential structure transformations that are exited during the case hardening, processes of case hardening can be divided into three logical parts: (1) carburizing, (2) hardening and (3) tempering [13] [14].

The group of works, which case hardening is constituted, is often presented in one operation, which is consisted of three parts, carburizing, hardening and tempering. Processes of carburizing, hardening and tempering are usually defined as sub-operations.

If the case hardening is done in some separated working places case hardening had to be divided into several operations. Case hardening with single quench hardening could be divided into three separate operations: (1) carburizing, (2) hardening and (3) tempering (Fig. 4, Table 4).

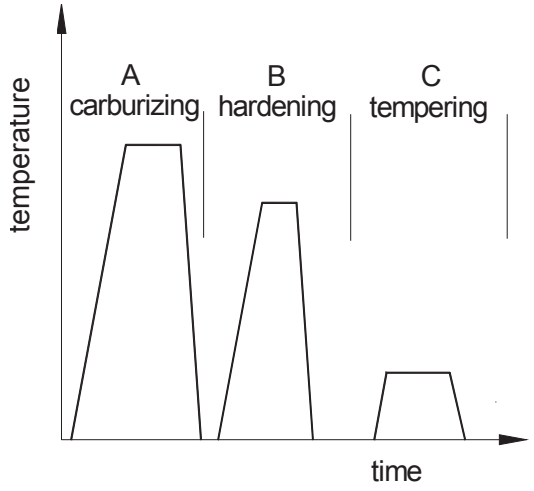

Fig. 4. Diagram of case hardening with single quench hardening

Table 4.
Operations of non-automated case hardening with single quench hardening

Operation number	Operation	Procedure parameters	Work place
XX*+1	Carburizing	x_{11}, x_{12},…	A
XX+2	Quench hardening	x_{21}, x_{22},…	B
XX+3	Tempering	x_{31}, x_{32},…	C

*XX is number of previous operation

Case hardening with direct quench hardening usually is better to divide into two operations, carburizing + hardening and tempering (Fig 5, Table 5).

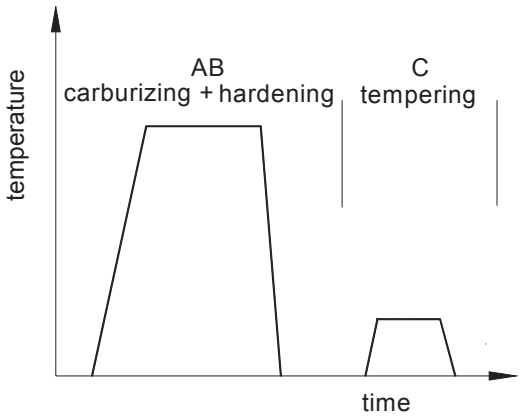

Fig. 5. Diagram of case hardening with direct quench hardening

Table 5.
Design of automated case hardening with direct quench hardening

Operation number	Operation name	Procedure parameters	Work place
XX*+1	Carburizing + Quench hardening	x_{11}, x_{12},…	AB
XX+2	Tempering	x_{21}, x_{22},…	C

* XX is number of previous operation

Automated process of case hardening with single quench, which has a same diagram as non automated process of case hardening with single quench (Fig. 4), must be designed into one operation, if it is all executed into one work place, i.e., a production device, (Table 6).

Table 6.
Operations of automated case hardening with single quench hardening

Operation number	Sub-operation number	Sub-operation	Procedure parameters	Work place
	XX+1.1	Carburizing	x_{11}, x_{12},…	
XX*+1	XX+1.2	Quench hardening	x_{21}, x_{22},…	ABC
	XX+1.3	Tempering	x_{31}, x_{32},…	

* XX is number of previous operation

Similar consideration could be accepted for anyone other similar heat treatment process.

3. Conclusions

Process planning of heat treatment has to be designed based on the same principles that are valid for other common manufacturing processes. In this way the heat treatment process planning is more appropriate to integral trends of manufacturing developments, i.e., with the trend of introducing the modern systems in all parts of manufacturing.

By analyzing of the process planning of quenching and tempering and case hardening it can be concluded that process planning of heat treatment must be based on the process performance, but not on the microstructure transformations and other chemical and physical processes that appear during the heat treatment.

Important activity in operation designing is identification of single works (sub-operation, holds) and defining their order of execution within operation. According to the characteristic of work place and work aim the way of sub-operation or hold execution must be defined.

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