How to cite this article:

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Title of article: „Computer-aided preparation of production of products for CNC lathe in an automated production line”
Mechanik, No. 7 (2019)DOI: <https://doi.org/10.17814/mechanik.2019.7.55>

Computer-aided preparation of production of products for CNC lathe in an automated production line

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The article presents possibility of using contemporary computer systems for computer-aided development of production preparation processes using numerically controlled machines. An example of preparing the production of a drive shaft of a motor shaft on a numerically controlled lathe Defum TAE45 in an automated production line is described. The correctness of the processed process was verified using a profile projector.

KEYWORDS: computer-aided production preparation, CAD/CAM systems

Introduction

Contemporary, automated production processes are increasingly implemented using advanced computer techniques [7, 8]. Therefore, CAD and CAD/CAM systems are increasingly used in the machine industry, which revolutionized the way of product design and the stage of technological preparation of production (including the choice of machine tool, development of individual machining operations, selection of tools and machining parameters, preparation of technological documentation) [3, 5, 6]. An important stage of work carried out in CAD/CAM systems is usually generating and outputting the control code to the selected CNC machine tool [1, 4]. The manufacturing process is verified using computer-aided measuring machines. An example of such an approach to the preparation of the detail design and its execution and implementation for processing is the process of preparing the production of the car axle shaft [2] presented below. This process was implemented for production on an automated drive shaft manufacturing line.

Development of the drive shaft construction

The paper presents the process of computer-aided preparation of the drive shaft production, which is an element of the car axle sub-assembly. The detail implemented in production - the drive shaft - is designed to transfer torque between the drive source and the driven sub-assembly. Joints, that are used in the axle shafts, must transfer torque when working at different angles. The design of the drive shaft assembly should therefore allow its length to be changed during operation. The developed project must take into account the power and capacity of the engine, performance and expected durability of the implemented detail.

The design took into account the amount of stress caused by the transfer of assumed loads. Places of construction, where the highest stresses occurred, are the grooves (notches), channels and ends of the splines. These are critical areas of the designed drive shaft. Any exceeding of the allowable stresses could cause the shaft of the axle to break and, as a consequence, no transmission of power to the wheels driving the vehicle.

Material used for the production of the designed axle shaft is C45 steel. As a semi-finished product, drawn rods 546 mm long and $\varnothing 28$ mm diameter were applied. Executive drawing of the axle shaft is shown in fig. 1.

Fig. 1. Executive drawing of the car axle shaft

Development of the solid model in CAD program

Development of the initial concept and implementation of unnecessary strength calculations allowed for the transition to the stage of computer saving of the structure using selected CAD system (SolidWorks). At this stage of work, it was decided to design with a help of 3D modeling. Currently, such modeling of three-dimensional objects is not only a starting point for making two-dimensional construction and technological documentation, but also makes it possible to carry out strength calculations (e.g. using the finite element method). The final shape of the axle shaft is shown in fig. 2.

Fig. 2. 3D axle shaft model

Preparation of construction documentation

Increasing use of 3D modeling systems clearly facilitates and speeds up the process of preparing the structural documentation of a designed object. Three-dimensional modeling eliminates the need for subsequent projections and views of an element, because all 2D documentation is created almost automatically (fig. 3) - this is how two-dimensional workshop drawing of the axle shaft was prepared (fig. 1).

Fig. 3. Development of 2D construction documentation for the axle shaft

Preparation of the production process

After preparing the construction documentation and drawings of the detail, as well as after specifying the requirements that the designed detail is to meet, one can proceed to the preparation of technological machining process. The process of making the car's axle shaft in an automated production line includes seven technological operations described below (fig. 4).

Upsetting the rod

During this operation, the ends of the axle shafts are upset on both sides.

The operation is carried out on the GFU upsetting press at the temperature of 900÷1050 °C and during 13÷15 s on each side. The operator checks the total length of the shafts several times with a caliper.

Centering and turning

The next operation involves centering and turning (fig. 4a) of the shaft surface after the upsetting operation. The upset shaft, shortened to 462 mm, is supplied by the operator to the feeder of the numerically controlled double-head AFM Defum NPF 120N. Drilling operations are performed on the fronts of the rollers, followed by planning of the axle shafts.

Turning

After machining in the centering roller, the roller travels with an automatic feeder to one of three AFM Defum TAE 45 N lathes. The lathe performs roughing and shaping operations of the shaft (fig. 5). In subsequent operations, the shaft ends are machined under the splines and the channel is cut under the snap ring. The operator checks the correctness of machining using gauges and calipers. During each production shift, the profile projector verifies compliance of the most important dimensions of the axle shafts obtained on each of the three lathes with control and measurement documentation.

Spline rolling

After obtaining the final shape, the shafts are transferred on an automatic feeder to the next machine - the Excellto Roto-Flo strip rolling mill, designed for rolling spline at both ends of the shaft (fig. 4b).

The wandering roller with automatic feeder is fastened in the centers and inserted between the rolling strips. After performing this operation, the operator checks the execution of the splines by means of gauges. After the operation, the shafts are placed on the feeder, on which they move to the next position.

Fig. 4. Technological process of the car axle shaft: a) centering and face turning, b) spline rolling, c) induction hardening, d) tempering, e) straightening, f) hard turning

Induction hardening and tempering

After reaching the quenching machine, the shafts are fastened at the centers. Fig. 4c shows the shaft before hardening (blue arrow) and during hardening (red arrow). During the operation, the axle shaft rotates and approaches the inductor during the rotation. Eddy currents begin to flow through the detail, creating a temperature of 800 °C. By manipulating such technological parameters as current voltage and heating time, the operator obtains the expected thickness of the hardened layer and its appropriate hardness. In the next operation, the feeder moves the details to the next inductor, where they are released (fig. 4d). Twice a shift, the operator checks the drive shaft from a specific quenching station.

Roller straightening

Automatic feeder transports hardened rollers to the straightener. After straightening several times (fig. 4e), the detail is detached and transported further. During this operation, the shaft runout is checked randomly (using a dial indicator) and the dimensions of the spline (using gauges). Once in a shift, the operator checks the drive shaft on the profile projector.

Hard turning

The next operation in the shaft production process is hard turning (fig. 4f), which replaced grinding. The head rolls both ends of the drive shaft where the bearings are to be mounted. With the help of gauges, the operator checks each processed piece.

Development of technological process for the shaft turning operation

The shaft is machined on an AFM Defum TAE45N [9] lathe (fig. 5) in one clamping (centerings were made during previous operation) and four machining operations. Those are:

- treatment No. 1 - roughing the entire length of the drive shaft and forehead planning from the tailstock side,
- treatment No. 2 - performing the shape machining on the entire length of the drive shaft,
- treatment No. 3 - finishing treatment at the ends of the axle shaft for splines and for bearing with a diameter of $\varnothing 30.3$ mm,
- treatment No. 4 - making the duct $\varnothing 28$.

Sandvik Coromant's tools (chucks and inserts) were selected for the planned treatments [10] and cutting parameters were adopted in accordance with the manufacturer's recommendations.

Fig. 5. Turning operation on the AFM Defum TAE45N machine tool

Technological documentation of the axle shaft turning operation was prepared. The lathe was programmed using the workshop programming method, directly from the machine control panel.

Checking the accuracy of the outline

The profile projector from Dr. Schneider company was used to verify the correctness of the process of car axle shaft machining. The method used to prepare the control programs (learning programming) is analogous to the methods applied in coordinate measuring machines. The projector also allows measurements to be made in manual control mode. The axle shaft during measurements is fixed in the centers (fig. 6).

Fig. 6. Measurements made on the profile projector

Summary

The paper presents an example of a comprehensive preparation of the computer-aided process of car axles production.

The use of modern computer systems to prepare production not only significantly speeds up the design and development processes of technology, but also significantly improves the quality of production processes.

Obtained results of measurements of machined detail prove the correctness of machine tools and tools selection.

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