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OBSERVATIONS ON THE DESIGN OF MANUFACTURING TECHNOLOGY USING ARTIFICIAL INTELLIGENCE

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The emergence and development of artificial intelligence programs led to the formulation of a question regarding the possibilities of using these programs, including for the design of manufacturing technologies. Such a problem is of interest both for industrial practice and for the training activities of future specialists in the field of manufacturing technologies at higher technical education. As such, it was proposed to solve the problem of designing a manufacturing technology for a cylindrical gear wheel with a bore using ChatGPT. The results obtained using ChatGPT were examined from the point of view of a specialist with some experience in this field. It was found that there are aspects in which the results obtained by the program exceeded expectations, as in other cases, the information was not quite correct or complete.

Keywords: artificial intelligence, cylindrical gear, initial information, manufacturing technology, operations, tools, devices, testers.

1. Introduction

A gear is a machine part equipped with teeth and used in the case of a gear for transmitting movement or torque between two other parts, most often two shafts. There are multiple criteria for classifying gears. According to one of these

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classifications, if the surfaces on which the teeth are located are taken into account, there are cylindrical, conical, hyperboloidal gears, etc. Gear manufacturing technologies are differentiated from each other by taking into account the shape and dimensions of the finished part, its material, the nature of the production, etc. [1-3].

The manufacturing technology of a part is understood as a set of information that refers to the stages of transforming the workpiece into a finished part intended to fulfill a certain role. If a few decades ago the design of a manufacturing technology was carried out by the technologist, in principle by completing a technological documentation, today, in many of the stages of designing a technology, the engineer is helped by the electronic computer.

The most advanced variant can involve the design of a technology practically without the direct involvement of a human being. The importance of designing the manufacturing technology of a part as optimally as possible results from the decisive influence that the technology can exert on the cost and duration of manufacturing a part.

To be able to design a manufacturing technology correctly, future specialists in this field, that is, students, go through, within specialized disciplines, stages designed to familiarize them with the specific problems of designing manufacturing technologies valid for different categories of parts.

Recent years have brought into the spotlight the concerns of *using artificial intelligence* to solve various problems, and some of these problems refer to the design of manufacturing technologies. In principle, artificial intelligence is based on the development of computer systems and computer software capable of performing tasks that are typically solved by human intelligence.

It is thus found that there can be a design of manufacturing technology assisted by artificial intelligence, but the design of the entire manufacturing technology by artificial intelligence must also be taken into account [4].

Without having been talking about the use of the concept of artificial intelligence, in Romania, at the beginning of the ninth decade of the previous century, a team of specialists from the "Traian Vuia" Polytechnic Institute designed a system for the automatic design of manufacturing technologies for mechanical parts, a system called SIGET [5].

By introducing information about the part to be manufactured, the computer program was able to develop a technological sheet-type document containing the information necessary for manufacturing and determining financial information about the manufacture of a part. Professor N.V. Ivan from Brașov proposed the use of a program developed by him and relating to the automatic design of technological processes for automatic lathes [3].

In a paper analyzing the current state of information regarding the use of artificial intelligence in the field of manufacturing, Gao et al. conclude that there are clear prospects for expanding the use of artificial intelligence in the field of manufacturing and achieving a so-called *intelligent manufacturing* [6].

Espina-Romero et al. have assessed that artificial intelligence applications transform manufacturing processes, improve the efficiency of these processes, and open up new business opportunities [7].

The study of the specialized literature highlights the existence of extensive concerns among researchers regarding the deeper evaluation of the possibilities of using artificial intelligence software for the development of various manufacturing technologies [8-13].

The objective of the research whose results were presented in this paper was to test the extent to which artificial intelligence can design a reliable manufacturing technology for a cylindrical gear. Attention was also paid to clarifying some aspects of training future engineers in the conditions in which artificial intelligence will be able to solve at least satisfactorily the numerous problems they will face. As such, several problems specific to the design of the manufacturing technology of a cylindrical gear were first addressed, and some of the solutions proposed by artificial intelligence were subsequently analyzed and commented on.

2. Brief observations on the design of manufacturing technology for a mechanical part

When designing the manufacturing technology of a mechanical part, it starts from the existence of some initial information. Such initial information concerns the existence of a correct mechanical drawing, the specification of the nature of the production (single-unit production, series production, mass production), the existence or possibilities of manufacturing/purchasing certain equipment (machine tools, tools, devices) and, respectively, the existence of operators capable of materializing the operations of manufacturing the part, as well as the existence of any special manufacturing conditions.

Starting from the initial information, the engineer or student involved in the development of a year project in a matter in the field of manufacturing technologies will choose a workpiece and will propose several operations whose materialization should lead to a part that corresponds to the conditions in the mechanical drawing, but also to some cost and productivity requirements.

Subsequently, the machining allowances and intermediate dimensions can be determined, which will ultimately allow the dimensions of the workpiece to be established.

For each of the proposed operations, processing conditions and time standards are determined. A final stage may involve determining technical and economic parameters for evaluating the proposed manufacturing technology and completing specific technological documents.

Fig. 1. Spur gear wheel designed using a configurator [14]

3. Computer-aided drafting of the part to be manufactured

In an attempt to test the possibilities of using artificial intelligence for designing the manufacturing technology of a cylindrical gear with straight teeth, it first resorted to computer-aided drafting of the part, using a configuration program intended for such an activity [14]. The main information entered when using the configuration program was that relating to the material of the part (C45 steel), the module (m=2 mm), and the number of teeth (z=20). The results of using the configurator can be seen in Figure 1; these results can, of course, be modified or completed by the user, by taking into account more specific information. In this way, it was proposed, for example, that the width of the gear be 20 mm. Since the configurator is proposed by a certain machine-manufacturing company, it is noteworthy that there is also an estimated price for the company to manufacture the part under analysis.

4. Definition of the design theme corresponding to the manufacturing technology of the cylindrical gear

To design a manufacturing technology for a cylindrical gear with straight teeth, the ChatGPT artificial intelligence program was used, the version valid on 7/09.2025 [15]. The conversation with the program was conducted in Romanian. The request was in the form: “Please develop the manufacturing technology for a cylindrical gear with 20 straight teeth, having a module m=20 mm, an outer diameter of 44 mm, an axial hole diameter of 20 mm, and a width of 20 mm, from a C45 steel workpiece”. It can be seen that the information provided was much too brief (intentionally), lacking, for example, information on the precision and roughness of the various surfaces, the specific technical conditions of a cylindrical gear with straight teeth, information on the equipment of the workshop/company in which the proposed technology will be implemented, the existence of operators with qualifications corresponding to the various processing that will be applied to the workpiece, etc. Moreover, by mistake, the value of the module was entered incorrectly (m=20 mm instead of m=2 mm).

5. Results obtained by using the ChatGPT program to generate the manufacturing technology for a cylindrical gear with straight teeth

A first surprising result was the identification by ChatGPT of the fact that the module may have been entered incorrectly. The program performed a check of the main dimensions of the gear wheel, finding a contradiction (the outer diameter valid for a module m=20 mm did not correspond to the requested one, D=44 mm). The ChatGPT decided to take into account a module value of m=2 mm.

Next, the ChatGPT presented, in separate sections, information regarding the design data, the workpiece, and the machining allowances, the proposed technological scheme (the sequence of operations necessary for the manufacture of the gear wheel), the indicative cutting regimes, the recommended tolerances, the tools, devices, and verifiers that can be used.

The design data taken into account or calculated by the program are those in Table 1.

Table 1

Design data (for an involute profile characterized by angle α°

Parameter imposed or determined by the program [15]	Comments of the authors of the paper
Modul m=2 mm	Parameter imposed by the theme
Number of teeth z=20	Parameter imposed by the theme
Dividing diameter d=mz=40 mm	Parameters calculated by the program. It is necessary to emphasize that ChatGPT performed calculations through which the sizing of some gear components was verified.
Outer diameter da=m(z+2)=44 mm	
Diameter at the foot df≈d−2.5m=35 mm (teeth full-depth, clearance c=0.25 mm)	
Circular pitch p=πm≈6.283 mm	
Base diameter db=d cos20°≈37.59 mm	
Tooth height: h=2.25m=4.5 mm	
Wheel width b=20 mm	Parameter imposed by the theme
Nominal bore: 20 mm (20H7 suggested if h6 shaft fit is required)	Parameter imposed by the topic (by topic, the accuracy level for the bore diameter was not specified)

The information regarding the workpiece and the proposed processing allowances is as in Table 2.

Table 2

Information proposed by ChatGPT regarding the workpiece and processing allowances

Information imposed or determined by the program [9]	Comments of the authors of the paper
Material: **C45** (1.0503).	Added the numerical symbol for steel.
Workpiece: rolled/forged bar Ø ~50 mm (or disc detached from the bar), gross length ~24–25 mm.	Valid recommendations
Recommended allowances: - on the side surfaces: +0.3…0.5 mm/side for grinding/finishing operations; - on the outer diameter (crown) for preliminary turning: +0.3…0.5 mm; - on the bore: for a 19.7–19.8 mm hole, finish by reaming with a 20H7 reamer.	In the proposed technology, lapping was also included as the last processing of the bore, a valid but less efficient process.

Table 3

Information regarding the sequence of operations

Technological information proposed by ChatGPT [15]	Comments of the authors of the paper
O0. Cutting a workpiece from a bar (band saw). Part marking	Cutting can also be performed on other machine tools.
O1. Turning: - Face planing 1; chamfer 0.5×45°. - Surface centering 1 (centering holes if working between centers later).	The centering hole may be necessary to locate the drill when starting to machine the axial bore.
O2. Regrinding – turning surface 2 and outer cylinder: - Face 2 planing → gross length 20,420 mm (depending on the allowance). - Turning guide cylinder Ø ~45 mm to Ø 44.2…44.5 mm (0.2–0.5 mm is left for finishing after toothing/induction hardening, if applicable). - Turning 0.5×45° chamfers on outer edges.	It is not clear how to locate and clamp the workpiece.
O3. Drilling and reaming the bore: - Pilot drilling Ø10–12 mm; then gradually widening. - Reaming to Ø 19.7–19.8 mm. - Finishing with reamer to 20H7 (20,000 / +0.021 mm). Entry/exit chamfer 0.5×45°. (Optional: if a key is required, O3a: broaching a keyway according to ISO – e.g., 6×2.8, tolerance JS9.)	The diameter of the hole resulting from the last enlargement was not specified. It is worth noting the reaming proposal, leading to a precision of the bore diameter that exceeds the design theme.
O4. Preliminary heat treatment (optional, recommended for C45): normalizing with heating to 840–880 °C, cooling in air → uniform structure, cutting stability.	It may be useful to specify the objective pursued by the preliminary heat treatment.
O5. Hobbing – for straight toothing: - Cylindrical tooth milling machine, with synchronized feed.	The information provided by ChatGPT is more

- Worm cutter module *m* = 2, pressure angle 20°, standard full-depth profile; correction *x* = 0 (unless otherwise required). - Guideline settings for unhardened C45: - **HSS tool**: *v* ≈ 50–80 m/min → choose ~60 m/min; emulsion cooling. - **Carbide tool:** *v* ≈ 120–200 m/min; minimum cooling/MQL or dry. - Axial feed *fzf* (mm/rev/tooth) for *m*=2: 0.08–0.18 mm/rev/tooth; choose 0.12–0.14 mm/rev/tooth, to ensure a certain balance between productivity and quality. - Total cutting depth: *h*≈4.5 mm (gradually enter in several passes, if necessary). - Machining starting at the tip diameter 44.0 ± 0.1 mm (unless another tolerance is specified). - Deburring immediately after toothing (using a brush and acting at the tooth tips).	extensive than in the cases of other operations. It would have been useful to include some symbols of the tools and devices used. There are no explanations on how to calculate the tooth height, but the result of the calculation is correct. For deburring, it could be more efficient to use a scraper. It is useful to specify certain tolerances.
O6. Heat treatments (depending on hardness requirement): - **Economical variant** (untreated gear at the tooth level): **hardening** + moderate volume recovery to 28–32 HRC → moderate stability/wear resistance. **- High-performance variant** (recommended for C45 steel): **induction hardening of the tooth:** 50–55 HRC, hardened layer with a thickness of 0.8–1.5 mm; low recovery to reduce stresses. - After treatment: check for deformations; if necessary, **grinding of the front surfaces** to a final length of 20.0 ±0.05 mm and **slight re-chamfering.**	It is worth noting that two heat treatment options are indicated, leaving the user to decide which option is more convenient. The second option could be recommended after a case hardening treatment for lower carbon steels.
O7. Tooth finishing (optional, depending on the accuracy class): - **Shaving** or **grinding of the flanks** for ISO classes 7–8, or for even higher accuracies. - For general parts, it can stick to processing with a worm cutter + deburring (ISO class 9–10)	Since the design theme does not specify the accuracy of the teeth, ChatGPT includes useful comments in this regard.
O8. Final inspection and marking: - Dimensional checks: dad_ada, ddd (by indirect checks), *b*=20.0±0.1, bore **20H7**; radial and end runout ≤ 0.03–0.05 mm, checking the coaxiality of the teeth with the bore (concentricity). - Teeth: - checking the height **over the rollers** or **tangential measurement on *k* teeth** (control of the average pitch and tooth thickness); - checking the backlash at the base (min. *c*=0.5 mm → *df*≈35 mm); - flank roughness after worm milling *Ra*=1.6–3.2 μm, after grinding *Ra*=0.4–0.8 μm. = If there is a keyway: solid gauges + gauge for width/position. - Material/batch marking on the front surface	Taking into account the lack of initial design data, it is noteworthy that ChatGPT took into account and resolved some actual technical control aspects, including by adequately completing some of the initial information.

It is noted that the information corresponding to the processing conditions (as well as those relating to the tolerances of the surfaces obtained by processing and to the proposed tools, devices, and verifiers) was not included directly in relation to the operations and phases mentioned in Table 3, but in separate sections of the document prepared by ChatGPT. This information was presented in tables 4, 5, and 6.

Table 4

Indicative cutting conditions proposed by ChatGPT

Information provided by ChatGPT [15]	Comments of the authors of the paper
Turning (carbide inserts): cutting speed 180–220 m/min, feed f=0.15–0.3 mm/rev, cutting depth ap=0.5–2 mm; emulsion cooling.	It is worth noting the relatively high values of the proposed cutting speed.
Reamer/reamer Ø20: HSS steel cutting edge, cutting speed v=15–25 m/min, abundant cooling-lubrication with emulsion	
Hobbing *m*=2 with HSS: cutting speed ~60 m/min; if the cutter has D = 60 mm → $n \approx v/(\pi D \approx 60\,000/(\pi \cdot 60) \approx 318$ rev/min; Total feed f resulting from fzf_zfz × no. of cutting edges. Adjust according to the machine tool.	Since the milling machine was not mentioned, it was not possible to select accessible speed and feed values.

Table 5

Information on recommended tolerances (ChatGPT mentions: "unless otherwise specified")

Information provided by ChatGPT [15]	Comments of the authors of the paper
- Bore: 20H7; shaft: h6 (for precise sliding mounting). - Wheel width: 20.0 ± 0.1 mm. - Outer diameter: 44.0 ± 0.1 mm. - Runout (towards bore): radial ≤ 0.03–0.05 mm; end ≤ 0.02–0.03 mm. - Tooth quality: ISO 1328-1 class 9 (general use) or 8 if ground.	It is worth noting the completion of the constructive design aspects, including some tolerances. The technological route did not take into account the application of a processing by grinding.

Table 6

Tools, devices, and testers

Information provided by ChatGPT [15]	Comments of the authors of the paper
- Universal chuck/mandrel or extension arbor for good concentricity when machining with a worm mill. - Worm mill m=2, α=20°, HSS or carbide; replacement wheels for ratio z=20. - Reamer Ø20 H7; conical reamers for chamfers. - Keyway broach (if applicable). - Dial gauge, micrometers, H7 buffer, measuring rollers ~Ø1.8–2.0 mm, and measuring micrometer over rollers / tangential measuring device	Not all tools and devices were indicated (the cutting tool and the device used to locate and clamp the workpiece during cutting were not mentioned, drills were not mentioned, etc.)

6. Observations from the examination of the technology proposed by ChatGPT

It is necessary to recall that the so-called initial data established by the applicant were intentionally incomplete, it being appreciated that a more extensive expression of this information would have complicated the development of the desired technology. For the same reason, but also due to the need to simplify the design theme, the gear wheel was not provided with a keyway, as it would be possible to place it on a shaft using a washer and a nut placed on a threaded step of the shaft.

In tables 1-6, some information provided by ChatGPT was written in bold, and this style was maintained, although the editorial recommendations indicate a different use of this type of character. A few pieces of information that were not sufficiently clear or that were written more than once were removed. On the other hand, some very brief information was added to make some formulations proposed by ChatGPT more explicit, but without altering the general ideas proposed by the program.

Sometimes, the program used abbreviated forms of concepts, as can be found in industrial practice.

Although the structure of the proposed technology presents components similar to the structure of the semester project in the manufacturing technology matters used in Romania, there are also some differences. Since the development of the technology by ChatGPT was carried out by consulting the information existing in its database (information previously collected from the web), it is expected that ChatGPT would have also taken into account the experience of other technology designers when it was exposed on the internet.

An incomplete recommendation was included regarding the verification of concentricity; a more complete and closer to reality request would have been to determine the deviation from coaxiality of the teeth in relation to the bore, or even a measurement of radial runout.

The general information about ChatGPT mentions that the data provided by the program can be wrong. It remains, therefore, a task for the engineer or student to have specialized knowledge and skills that allow them to identify possible mistakes made by the program. It is therefore necessary for educational programs to emphasize such an issue: engineers and students must know how to develop a technology, to be able to more easily identify possible mistakes, and, perhaps, to improve the proposed technology, to avoid the occurrence of these mistakes.

Tabulated values were probably used for some parameters and not calculated values. In the conditions of a semester project in a technological matter, at least in some cases, the processing allowances can be determined both by using mathematical relations and by taking them from tables. A comparison of them will eventually be carried out to show that, for safety reasons, the allowances in the tables are generally greater than those determined using mathematical relations.

The technical terminology used by ChatGPT can be considered acceptable. As mentioned, sometimes the information provided by ChatGPT was written in a succinct form, but expressed clearly enough what needs to be done; in the tables included in this work, the information provided by ChatGPT was supplemented or modified to a small extent to make the comments of the authors of the work clearer.

The devices, tools, and verifiers indicated by the program were not entirely the most appropriate for achieving the objectives for which they were proposed. For example, the locating and clamping of the workpiece when machining teeth with a worm-module milling cutter does not seem to be possible directly in a chuck, as is the locating and clamping on a fixed mandrel, i.e., on a device that includes several components.

If it takes into account the possibility of using ChatGPT when designing technologies for manufacturing mechanical parts by students, it becomes of interest to accumulate sufficient knowledge that allows students to verify the validity of the information provided by ChatGPT. It may be necessary, as such, to pay greater attention to training students on the verification of technologies, an activity encountered in the case of heads of technological design departments in companies, who must, in fact, sign to confirm the validity of the proposed technologies.

7. Influence of initial conditions on the proposed manufacturing technology

Changing the information considered as initial conditions for designing the manufacturing technology of a part will lead to changes in the actual content of the technology proposed by the artificial intelligence software. Thus, providing additional information regarding the part to be obtained, the type of production, the machine tools, and the available tools will lead to a more justified consideration of such categories of information. For an example of how the type of production could lead to changes in the manufacturing technology of the gear wheel, whose technology was previously proposed by the ChatGPT artificial intelligence software, a new question was formulated to the aforementioned software. The question even followed the possible changes for different types of production. A synthetic version of the answer provided by the software [16] is the one in Table 7.

Table 7

Comparison of different technologies proposed by artificial intelligence by considering the type of production [16]

Criterion	Individual production	Small batch production	Medium series production	High volume production	Mass production
Production volume	1–10 pcs.	tens–hundreds of pcs.	hundreds–thousands of pcs.	tens of thousands of units	hundreds of thousands – millions
Main purpose	Flexibility, minimum setup cost	Moderate repeatability	Productivity + quality	Minimum unit cost	Max. productivity
Semi-finished product	Rolled bar	Bar/free forging	Die forging	Precision forging	Advanced plastic deformation

Processing allowances	Large	Medium	Small	Very low	Minimum
Machine tools	Universal	Universal + semi-automatic	Specialized / CNC	Automated lines	Fully automated lines
Turning (Ø, hole)	Universal lathe	Universal lathe/semi-automatic	CNC lathe	Dedicated CNC lathe	Automatic/integrated line
Gearing process	Module milling	Module milling/worm milling	Snail milling	High-speed worm milling	Rolling/rolling teeth
Tools used	Standard tools	Standard + dedicated tools	Dedicated tools	Specialized tools	Special tools
Productivity	Very small	Small–medium	Medium–large	Large	Very large
Accuracy achieved	Class 8–9	Class 8	Class 7–8	Class 6–7	Class 6
Heat treatments	Rare	Occasional	Frequently	Standardized	In-line integration
Quality control	Manual	Manual + templates	Dedicated devices	Automated	100% automated
Unit cost	Very large	Large	Medium	Small	Very small
Initial investments	Very small	Small	Medium	Large	Very large
Flexibility	Very large	Large	Medium	Low	Very small

An analysis of the information in Table 7 confirms the validity of the observations made by the artificial intelligence software, without, however, all the information being sufficiently well justified. Thus, for example, more complete information would have been the use of a stamped semi-finished product in the case of mass production. Also, the fact that the gear wheel must be manufactured from a steel that is to be subjected to heat treatments would have required the inclusion of such a treatment for any type of production, the information provided by the software in this case being less adequate.

8. Conclusions

The objective pursued by the research undertaken was to verify the extent to which, currently (September 2025), ChatGPT can provide a sufficiently clear and correct technology, when only very brief initial information was mentioned for a design topic of a manufacturing technology valid for a relatively simple part (cylindrical gear with straight teeth). ChatGPT has proven capable of proposing a technology that is quite sustainable and susceptible to completion when the issue of its application in practice arises. It is worth noting that the verification, correction, and completion by ChatGPT of some tooth dimensioning elements. It can be concluded that, in its current form, ChatGPT can provide a student or engineer with useful information in technological design, but this information still needs to be completed or modified by the ChatGPT user. It is necessary for the student to have knowledge that allows him to perceive the possibilities of completing and improving the technology, and an important role in this direction belongs to the university's matters of manufacturing technologies in specialized higher education. In the future, it is planned to test the possibilities of using ChatGPT also in the case of the need to design manufacturing technologies for other categories of parts in machine manufacturing, as well as to place greater emphasis on training future specialists in the field of manufacturing engineering with aspects related to the verification and improvement of technologies proposed by artificial intelligence programs.

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