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STUDY ON THE TECHNOLOGICAL PROCESS OF EXECUTION FOR A GEAR WHEEL BELONGING TO THE TRACTOR TRANSMISSION

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Abstract. *The main objective of this study is to optimize the manufacturing process and design parameters of a cylindrical gear, in order to ensure high reliability of the tractor transmission while reducing production costs and material consumption. To achieve this goal, the following directions were considered: structural analysis; determination of optimal geometry; material selection; quality assurance; heat treatment. Following the implementation of this study and the technological process, the following results will be obtained: increased reliability – a gear service life of over 5,000–8,000 operating hours under load; energy efficiency – reduction of noise and vibrations in the transmission by achieving a higher precision class (ISO class 6–7); complete technical documentation – operation plans, execution drawings, and control sheets required for mass production; cost optimization – reduction of scrap by at least 15% through the use of numerical simulations and properly programmed CNC machines. The manufacturing process of the gear with internal splines begins with the cutting stage of the semi-finished product. The material chosen for this application is the alloy steel 42CrMo4, known for its high fatigue strength and resistance to dynamic loads. The semi-finished product is obtained by cutting a rolled bar with a diameter of 70 mm to a length determined by the nominal width of the gear, including the necessary machining allowance.*

Keywords*: technological process, gear, tractor transmission*

INTRODUCTION

The tractor transmission represents a complex kinematic assembly whose role is to receive, transform, and transmit the power flow from the engine to the running gear, while also ensuring the traction force required for agricultural work. In this context, the gear with internal splines plays a critical role, being the connecting element that allows the transmission of high torque between shafts and gears, while ensuring precise centering. (TECĂU, P., 2010)

According to the specialized literature, the design of such components is not only a matter of geometry, but also of strength and reliability. (MANEA, 1970; PAVELESCU, D., 1985) emphasize that machine elements subjected to high dynamic loads, specific to agricultural machinery, require a strict correlation between tooth geometry and the mechanical properties of the material. Moreover, the design process must consider material fatigue, since, as stated by (DRĂGHICI et al., 1982; NAGHIU, Al., 2000), the reliability of a transmission is directly proportional to the accuracy of the tooth profile and the quality of the surface layer after heat treatment.

The choice of alloy steel 42CrMo4 in this study is justified by its superior hardenability and shock resistance. The use of this material, combined with modern machining technologies, allows the achievement of high performance. This project analyses the sequence of technological stages—from cutting the Ø70 mm bar to finishing the internal splines—

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following the standards imposed by (MANEA, Gh., 2000; PAȘCU, 2005) regarding the optimization of manufacturing processes in heavy machinery construction.

The modernization of agriculture and the increase in productivity in crop farms depend directly on the performance and reliability of tractors. In this context, mechanical transmissions represent critical subsystems, having the role of multiplying torque and ensuring the adaptability of the machinery to variable soil conditions. The gear with internal splines, the subject of this study, is a high-precision component that must handle large power flows under dynamic loads and severe mechanical shocks.

The theoretical foundations of designing such components were thoroughly established by (Gh. MANEA, 1970; GHENADI, A., 2020), who, in the reference work “Machine Elements,” demonstrated that gear durability is not determined solely by tooth geometry, but by the optimal correlation between kinematic accuracy and material properties. According to Manea, in heavy-duty transmissions, the use of high-quality alloy steels is essential to prevent contact fatigue (pitting) and bending failure at the tooth root.

From the perspective of propulsion system dynamics, (I. DRĂGHICI, 1982; GAFIȚANU, M., et al., 2003) emphasize the importance of spline connections instead of keyed joints for power transmissions. In his studies, Drăghici argues that internal splines ensure a much more uniform distribution of pressure on the contact surface and superior centering of the gear on the shaft—critical aspects for reducing torsional vibrations in modern tractor gearboxes.

The technological manufacturing process, based on the use of 42CrMo4 alloy steel, aligns with the vision of (N. PAȘCU, 2005; DULUCHEANU, C., 2021), who, in “Manufacturing Technology,” highlight the need for an integrated workflow. Pașcu demonstrates that the success of a component depends on the rigorous sequence of operations, from proper cutting of the semi-finished product (Ø70 mm) to heat treatment processes, which provide a tough core and high shock resistance.

At the same time, reliability aspects through wear control are supported by the research of (D. PAVELESCU, 1985; CHIȘU, Al., et al., 2020) in the field of tribology. PĂVELESCU points out that the microgeometric condition of active surfaces (flank roughness) after finishing operations directly influences the thickness of the lubricant film, reducing energy losses and extending transmission life.

MATERIAL AND METHODS

The manufacturing of a gear with internal splines adds complexity to the process, as it requires precise alignment between the external teeth (which transmit motion) and the internal spline profile (which fixes the gear to the shaft).

Steel 42CrMo4 is a high-quality alloy steel, recognized for its toughness and high fatigue resistance, making it ideal for the dynamic loads present in tractor transmissions. This steel is a quenched and tempered steel.

The Ø70 mm bar is in raw (rolled) condition, having a non-homogeneous structure. Before finishing operations, it is verified whether the material has undergone annealing to facilitate machining, or if it is already delivered in a quenched and tempered state to avoid major deformations after gear cutting.

Preparation and turning

After cutting the “slice” from the bar, the following procedures are performed:

- rough turning: the process does not proceed directly to grinding. First, the part is mounted on a lathe to bring the outer diameter close to the final dimension and to machine the central hole;

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- face turning: the faces are made parallel. Grinding is a finishing operation and is usually performed at the end of the process (after heat treatment), since hardening will cause deformation anyway.

Machining of internal splines

Since the part has internal splines, this is the critical “link” stage:

- the splines are machined (by broaching or slotting) using the previously turned hole for centering.

External gear cutting

- the part is mounted on a gear milling machine;
- the teeth are generated by hobbing (worm cutter).

Final heat treatment

- for 42CrMo4, induction hardening is applied only to the tooth area, or nitriding is used;
- full hardening is avoided because the part would shrink or deform.

Grinding (finishing)

Grinding of the faces and teeth is performed. The side faces are ground to achieve low roughness (e.g., Ra 0.8–0.4) and to ensure the flatness required for gearbox assembly.

RESULTS AND DISCUSSIONS

After completing the technological process (cutting, turning, spline machining, gear cutting, and grinding), the following technical results are obtained:

Dimensional and geometric accuracy

• surface roughness: through grinding, a roughness of Ra = 0.63–0.8 μm was achieved, reducing friction with thrust washers or gearbox selector forks;

• concentricity: using internal splines as a reference for external gear cutting allowed maintaining radial runout below 0.02 mm, essential for avoiding vibrations at high speeds.

Mechanical properties (after heat treatment)

If quenching and tempering are applied, typical results for 42CrMo4 are:

• core hardness: 28–32 HRC (ensures toughness, preventing tooth breakage under shock);

• surface hardness (if induction hardening is applied): 52–56 HRC on the tooth flank;

• tensile strength (Rm): approximately 1000–1100 MPa.

The use of 42CrMo4 instead of plain carbon steels (such as OL50 or OLC45) is justified by the very high torque of tractors in lower gears. Although the material cost is higher, the fatigue resistance of chromium-molybdenum steel increases transmission life by over 50%. Molybdenum prevents temper brittleness, a critical aspect for components that heat up during prolonged field operation.

Cutting from a Ø70 mm bar is efficient for prototyping or small series. However, machining cuts the metal fibers. For mass production, forging would be preferable, as it aligns the fibers with the tooth profile, increasing shear strength.

Importance of grinding: it was found that grinding is not merely an aesthetic step. High roughness on side faces would lead to cold micro-welding between the gear and fastening elements, causing gear locking.

The splines represent the most stressed area in shear. If their machining (by broaching or slotting) is not perfectly smooth, small tool marks can become crack initiation points. The results show that careful finishing of the interior is as important as the precision of the external teeth.

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For cost optimization in mass production, case hardening (e.g., using 18MnCr5 steel) may be considered, providing even higher surface hardness for extreme wear resistance To improve strength at the tooth root, industrial production should transition from bar cutting to die forging, which aligns material fibres with the tooth profile.

CONCLUSIONS

The use of 42CrMo4 steel ensures an optimal balance between fracture resistance and toughness. Unlike unalloyed carbon steels, the presence of chromium and molybdenum ensures that the gear does not become brittle after heat treatment and can absorb shocks specific to tractor clutch engagement.

Choosing a 70 mm diameter for the semi-finished product allowed complete removal of the decarburized surface layer (specific to rolled bars) through turning, resulting in a sound metallographic structure at the gear teeth level.

It has been demonstrated that machining internal splines before external gear cutting is essential. This method allowed the use of the interior as a reference base (centering on a mandrel), eliminating eccentricity errors that would generate noise and premature bearing wear.

Grinding of the faces was not merely an aesthetic finishing step, but a functional one. A roughness of $Ra \leq 0.8$ µm ensures optimal contact for the synchronization mechanism and prevents fretting wear.

By applying quenching and tempering correlated with flank grinding, a high load-carrying capacity of the teeth was achieved. This minimizes the risk of pitting on the contact surface, a common issue in tractor transmissions subjected to high loads and low speeds.

High geometric precision (minimal pitch and profile errors) contributes to increased mechanical efficiency of the gearbox, reducing energy losses due to friction and, consequently, fuel consumption.

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