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THE PRECISION INDEXES ANALYSIS OF TOOTHED GEARS MANUFACTURED BY PLASTIC DEFORMATION

Lucian BUTNAR, North University of Baia Mare, Romania

ABSTRACT: *The paper studies the dimensional and form precision, the surfaces roughness aspects in toothed gears manufacturing through different plastic deformation proceedings. It analyses the tools wear and its influence of manufactured toothed gears precision indexes.*

1. Introduction

The plastic deformation manufacturing of toothed gears used various proceedings which assure comparative to cutting manufacturing, a lot of advantages: material saving, high physical and mechanical attributes, superior productivity and low manufacturing costs in proper ranges.

The precision of toothed gears manufactured through plastic deformation is high, comparable with cutting manufactured gears and it depends of a lot of factors:

- The manufacturing procedure;
- The deformation tools precision;
- The deformation tools wear;
- The deformation installation state of repair;

The warm plastic deformation proceedings are usually „teeth jacking" processing which preserve a processing addition for the next cutting proceedings.

The cold plastic deformation proceedings can be only a „teeth jacking" processing followed by the final cutting or, frequently, a final processing of toothed gear. The dimensional and form precision can reach the IT 6 ISO stair of precision which means a teeth grinding. The minimal roughness of flank can reach 0,2...0,4 μm. These performances can be obtained in some plastic deformation proceedings through a single „jacking" and a single „finishing" processing or in some proceedings, just once.

The dimensional and form precision and the flank surface quality given by different proceedings through plastic deformation teeth manufacturing, using tools with the wear in prescribed limits is presented in the 1st table.

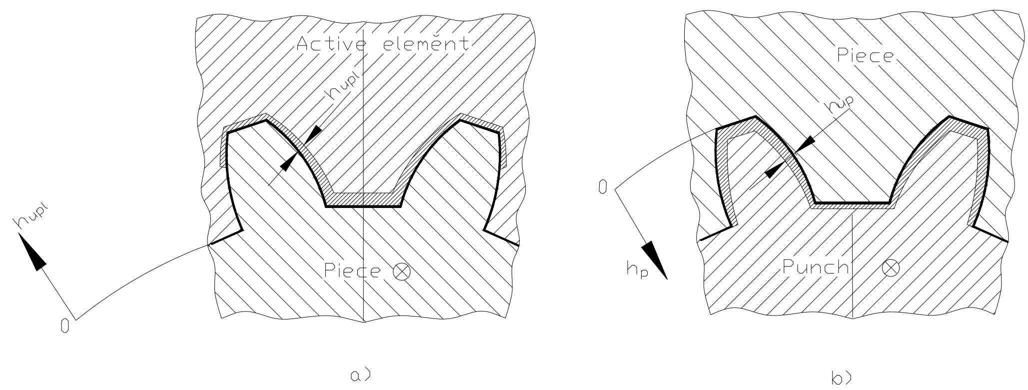
The 1st table

<table>
<tr><th>No.</th><th>The procedure</th><th>Technological particularities</th><th>The gear precision</th><th>Remarks</th></tr>
<tr><td rowspan="2">1.</td><td rowspan="2">The extrusion</td><td rowspan="2">- Warm or cold
- For a single module and a special tooth number;
- Internal or external teeth.</td><td>IT 6-8;
$R_a = 0,2$</td><td>Final processing</td></tr>
<tr><td>IT 9-10;
$R_a = 1,6$</td><td>Jacking</td></tr>
<tr><td rowspan="3">2.</td><td rowspan="3">The without fin molding</td><td rowspan="3">- Warm;
- For a single module, a special tooth number, and a single profile.</td><td>IT 7-8</td><td>Final processing</td></tr>
<tr><td rowspan="2">IT 9-11
$R_a = 3,2…1,6$</td><td>Jacking</td></tr>
<tr><td>Reconditioning procedure</td></tr>
<tr><td rowspan="2">3.</td><td rowspan="2">The punching</td><td rowspan="2">- Warm or cold
- For a single module, a special tooth number, and a single profile.
- Internal or external teeth</td><td>IT 8-12
$R_a = 1,6…6,3$</td><td>Usual precision</td></tr>
<tr><td>IT 6-8
$R_a = 0,2…0,6$</td><td>High precision</td></tr>
<tr><td>4.</td><td>The contour calibration</td><td>- Cold
- For a single module, a special tooth number, and a single profile.
- Internal or external teeth</td><td>IT 6-7
$R_a = 0,8$</td><td>Final processing</td></tr>
<tr><td>5.</td><td>The rolling (GROB)</td><td>- Cold;
- Module m = 1 – 3,5;
- Max. diameter d = 120</td><td>IT 7 –8
$R_a = 0,8$</td><td>Jacking rolls
Finishing rolls</td></tr>
<tr><td>6.</td><td>The teeth manufacturing with gear - tool (INCREMENTAL)</td><td>- Cold;
- m < 3,5</td><td>IT 8-10</td><td>Radial or axial advance
3 radial tools at 120^0</td></tr>
<tr><td>7.</td><td>The teeth manufacturing with rack - tool (ROTO–FLO)</td><td>- Warm or cold
- For a single module, a single height and profile;
- m = 0,3–2; d = 80-150</td><td>IT 9-11</td><td>Needs a rectification
A single processing</td></tr>
<tr><td>8.</td><td>The teeth manufacturing with worm - tool (ROLLMATIC – MAAG)</td><td>- Warm;
- For a single module, without profile correction;
- The tooth number, the profile, width and the tooth direction is diversifying;
- Internal gears d >200</td><td>IT 9-10</td><td>Jacking</td></tr>
<tr><td>9.</td><td>The teeth manufacturing with toothed sector (WPM)</td><td>- warm;
- For a single module, a special tooth number and a single width.</td><td>IT 9-11</td><td>A single processing</td></tr>
</table>

2. The precision and the wears of deformation tools

The execution precision of deformation tools is in connection with the wished precision of manufactured gear. Generally it is recommended that the deformation tools must have 2-3 higher levels of precision more than the manufactured gear. Also, the active surfaces have to be rectificated on 0,2…1,6 μm roughness. The form and dimensions of tool's active zone are determinate for each procedure intended the form, dimensions and wished precision for the toothed gear. When we have a correct manufacturing, we have the precision performances from the 1st table.

The complex plastic deformation couple formed on the tool – piece contact generates wearing phenomenon which are different in technical dry friction and in lubricated friction. In plastic deformation proceedings we have especially: adherence wearing, abrasion wearing, impact and rarely fatigue wearing.



The 1st fig. The wear of extrusion tribosystem in transversal section:
a) the direct extrusion of external teeth; b) the inverse extrusion of internal teeth.

The manufactured tooth gears precision is negative influenced by the manufacturing tribosystem wear h_u. The tool for teeth manufacturing must have a different treatment in punching proceedings and in properly plastic deformation proceedings.

In punching proceedings, the manufactured teeth precision is direct influenced by the precision and wearing of booth tools: punch (h_{up}) and the active plate (h_{upl}). The total wear of tribosystem punch – cutting plate in the supposed transversal section is:

$$h_u = h_{up} + h_{upl} \tag{1}$$

The clipping facet state modification by wearing produces a local increasing of the play $j \rightarrow j'$. There appear local angles α or γ, others than the initial established. They will modify and amplify the plastic deformation zone $SP \rightarrow SP'$ and they will have a negative influence on the material flowing and chopping. The micro-fissures are propagating in different directions making material breaking and fit apparition. The cutting flank roughness is worsening.

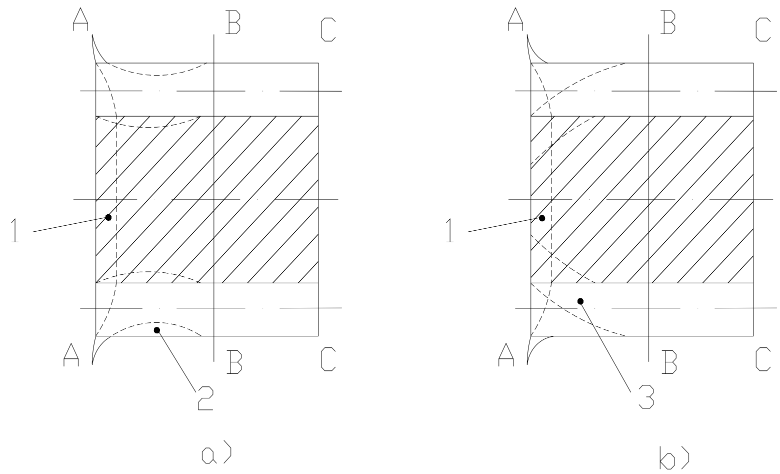
In properly plastic deformation proceedings the manufactured tooth gears precision is influenced only by the precision and the wear state of a single tool: punch (h_{up}) in internal teeth and the active plate (h_{upl}) for the external teeth. The tribosystems wear is reduced framed only by the generator active element. In transversal section it is:

$$h_u = h_p \text{ or } h_u = h_{upl} \tag{2}$$

The non-existence of clipping facets lags the wear manifestation on the piece quality and precision parameters. There also appear modifications of indexes of teeth precision and flank roughness.

3. The influence of deformation tool wear on manufactured teeth precision

The punching tools wear produces dimensional and formal modifications of manufactured toothed gear – the 2nd figure. Similar influences (less fit) are finding on the properly plastic deformation manufactured toothed gears.



The 2nd fig The tool wears influence on the toothed gear form: a) fit–1, flexion-2; b) conicity-3.

According to the generation principles, the tooth flank precision depends only by the base circle radius precision. The impossibility of practice measurement of this element needs a determination for precision indexes according to STAS 6273-81, ISO 1328, DIN 3960 for the wished level of precision and the criterion of functional role.

- *The radial beating of teeth (F_{rr})* – characterizes the cinematic precision criterion; it appears because of tool errors, non-uniform wear and manufacturing tribosystem instability;
- *The tooth profile digression (f_{fr})* vis a vis the theoretical evolventic profile, - characterizes the facile functioning criterion and it appears because of gear form modification in contact zone (A – B) next to the wearing active element;

- *The tooth direction digression ($F_{\beta r}$) in the frontal plan* – characterizes the contact criterion and it is produced by the execution errors of tool, the material breakings concurrent with the chopping by wearing tools and technological system instability;
- *The tooth thickness digression on the constant string (E_{cr})* – characterizes the criterion of the play between the flanks and it is clung to the gear body conicity and teeth evolventic form modification of the flank;
- *The mark digression over the teeth (E_{wr})* – characterizes the cinematic precision criterion and the play between flanks criterion, it is a complex index which proves the existence of tooth thickness errors, of the step and profile errors.

The analysis of deformation manufacturing tribosystems, of form and of tools wearing evolution, has permitted the creating of influence board of deformation tool wearing on the dimensional and form precision of manufactured toothed gear – the 2nd table.

The 2nd table

The procedure		**The gear diameter**	**Digression of tooth thickness**		**Gear fit**	**Gear conicity**	**Mark degression over the teeth**	**Direction digression**	**The radial beating**	**Flank form digression**
			Head	**Foot**						
Cutting **(external teeth)**	Wear P.	-	-	-	x	(x)	-	x	x_A	x
	Wear P.A.	↑	(↑)	↑	-	x	↑	x_A	x	x
	Wear P+PA	↑	(↑)	↑	x	x	↑	x	x	x
Perforating **(internal teeth)**	Wear P.	↓	(↑)	↑	-	x	↓	x_A	x	x
	Wear P.A.	-	-	-	x	(x)	-	x	x_A	x
	Wear P+P.A	↓	(↑)	↑	x	x	↓	x	x	x
***Direct extrusion* (external teeth)**	Wear P.	-	-	-	-	-	-	-	-	-
	Wear P.A.	↑	(↑)	↑	-	-	↑	(x)	(x)	x
Inverse extrusion **(internal teeth)**	Wear P.	↓	(↑)	↑	-	-	↓	(x)	(x)	x
	Wear P.A.	-	-	-	-	-	-	-	-	-
***Pressing with role tool* GROB**	Role wear	(↑)	(↑)	↑	-	-	↑	-	(x)	x

The P and PA notations mean punch and active plate. The presenting dates are relegating to a normal section in median zone (B-B). The reference to an other section is made through the index (x_A). The (x) notation means a *possible* apparition. The (↑), (↓) notations means a possible variation.

Depend on different real parameters variation, some unforeseeable variations might appear.

4. Conclusions

The analysis and the results are permitting the next conclusions:

- the gear precision is stark influenced by the tool wear in punching process;
- the tool wear influencing is lower than in volume stamping;
- for the external gears punching, the active plate wearing has a decisive influence on the gear precision;
- for the internal gear punching, the punch wear has a decisive influence on the gear precision;
- in volume stamping processing's, there is no fit or conical surface;
- the punch wearing has no influence on gear precision in direct extrusion;
- the active plate wearing has no influence on gear precision in inverse extrusion;
- the tooth form generally diversifies through thickening on foot bat because of conicity and breakings in cutted section, in AA – BB zone, it is possible the apparition of its whittling.

5. References

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