THE INFLUENCE OF THE LUBRICATION ON THE DURABILITY OF THE HIGH RESISTANCE SINTERED BUSHINGS OF THE CARDAN JOINTS WITHIN THE AGRICULTURAL EQUIPMENT

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Abstract: In order to produce agricultural technologic equipment with a high number of extremely dinamically and statically stressed parts it is important to take into account the possibilities offered by the new fabrication technologies of such parts. Such a possibility is offered by the powder metallurgy. The present paper presents the results obtained at the trials made by INMA București, Cluj-Napoca branch, to establish the influence of the lubrication on the durability of the sintered bushings of the B1 cardan transmission joints, made by BINACCHI and used in the SPC6-M sowing machine and other agricultural equipments like the ones for fitosanitary treatments and fertilizers administration.

INTRODUCTION

The huge advantages of the technologies of high resistance parts fabrication of powder metallurgy over the classical technologies from the point of view of the superior mechanical characteristics of the obtained parts as well as a reduced consumption of energy and a decreased pollution of the environment lead to the extension of the usage of domains of parts sintered from metallic powder.

Such a domain is the one of technological equipments for agriculture, to which belongs a great number of parts extremely strained statically as well as dinamically. The validation of the sintered parts usage involves the checking of their behavior in simulated and accelerated conditions.

The research objective that lead to the results presented in this paper consisted of certain trials to establish the influence of the lubrication on the durability of the sintered bushings of the B1 cardan transmission joints, made by BINACCHI and used in the SPC6-M sowing machine and other agricultural equipments like the ones for fitosanitary treatments and fertilizers administration.

Two categories of bushings made of Ancorsteel 2000 Hoeganaes steel powder. The first category was made of 4 sintered bushings and the second of 4 bushings sintered and boiled in oil.

The marks were made by SC Sinterom SA. These were checked, signed for and offered to INMA for tests by SC Tehnomag CUG SA Cluj-Napoca.

The checked parameters were the bushings temperature and their changing of form and dimensions due to the wear.
2. MATERIAL AND METHOD

A test stand designed and built by INMA Bucuresti as well as measure and control instrumentation have been used for trials and parameters measurement. Through its components and functioning the stand ensures both the torsion moment that strains the cardan shaft joints and the possibility of achieving more functioning angles of the cardan shaft.

**Stand Components:** The main trial stand parts are presented in Fig.1.

![Fig. 1. Components of stand for bushings’ test](image)

1-Supporting frame, 2-Electric motor, 3-Belt gearing, 4-Cover for belt gearing, 5-Cardan shaft, 6-Cover for cardan shaft, 7-Pump, 8-Suction pipe, 9-Discharge pipe, 10-Tank, 11-Pressure gauge, 12-Pump pressure regulating valve, 13-Switch

**Stand Functioning:** The cardan shaft takes the rotation motion from the motor through a belt gearing and transmits it to the pump. The pump’s role is to create the resistance moment necessary for the torsion stress of the shaft’s joints. The value of this moment depends on the pressure realized by the pump, pressure that changes with the operating of the valve on its discharge pipe. The pressure value is indicated by the pressure gauge situated nearby the valve. The holes in the frame allow the movement of the pump in a direction perpendicular on its axis, achieving this way four inclination angles of the cardan shaft: 5°, 10°, 20° and 30°.

The way the cardan shaft cover is fixed allows its quick handling in order to measure the temperature and to observe the joints.

**Measure and Control Instrumentation:** The following instrumentation has been used to measure the parameters during the trial, along with the pressure gauge installed on the stand: digital multimeter type UT58A/B/C with a measuring range between -40°C and 1000°C and measuring precision of 1°C; digital electronic slide gauge with the measuring range between 0 and 200 mm and measuring precision of 0.01 mm; outside micrometer with a measuring range between 0 and 25 mm and measuring precision of 0.001 mm; inside micrometer with the measuring range between 0 and 30 mm and measuring precision of 0.001 mm

**Testing Method:** The methods indicated in the catalogues of BINACCHI, Italy [1], WALTERSCHEID GmbH, Germany[2] and INVOLINI, Italy [3] were used to establish the trial method and program. The cardan shaft life is determined by the life of sliding bearings formed by the bushings with the crosses’ shafts, life that depends on the moment, rotation speed and on the inclination angle of the shaft.

The shaft’s torsional has been calculated taking into account the values of the power and of the rotations number at which the pump is used within the stand. The needed power for pumps’ drive was determined from his working diagram [3], for a shaft rotation speed of 540 rot/min. It result as on Fig. 2 is presented, a drive power of 11.2 kW.
To this rotations number the pump achieve a capacity of 110 l/min and a pressure of 49 bar. Thus:

\[ M_1 = 9549 \frac{P[kW]}{n[rot/min]} = 9549 \frac{11.2}{540} = 198[N \cdot m] \]

The test time in normal exploitation conditions has been determined using the Binacchi chart for the stand data, i.e.: a cardan shaft size 1, a torsional moment of 198 Nm, a shaft rotation speed of 540 rot/min (Fig.3).

![Fig. 2 Determination of pumps' drive power](image)

![Fig. 3 Chart of cardan transmission testing](image)
For the trials in accelerated conditions a balanced distribution of these hours has been adopted. At the same time, without knowing the life of the new bushings, it has been decided to perform series of trials at time values of a quarter of the accelerated trial time, and if the bushings resist, the trials will be made again until the total time of accelerated trial is up, finally measuring the bushings' wear.

The results on the chart and the ones obtained from these processes’ application are presented in Table 1.

<table>
<thead>
<tr>
<th>Inclination angle of cardan shaft [°]</th>
<th>Test time in the chart [hours]</th>
<th>Weight [%]</th>
<th>Time of accelerated test [hours]</th>
<th>Time of test on series [hours]</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1200</td>
<td>1/12</td>
<td>8.30</td>
<td>100</td>
</tr>
<tr>
<td>10</td>
<td>550</td>
<td>1/6</td>
<td>16.70</td>
<td>92</td>
</tr>
<tr>
<td>20</td>
<td>136</td>
<td>1/4</td>
<td>25.0</td>
<td>34</td>
</tr>
<tr>
<td>30</td>
<td>28</td>
<td>1/2</td>
<td>50.0</td>
<td>14</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1/1</strong></td>
<td><strong>100.0</strong></td>
<td></td>
<td><strong>240</strong></td>
</tr>
</tbody>
</table>

The trials: The sintered marks have the form presented in fig. 3,b and were approved and dimensionally checked before being installed on the crosses of the cardan joint.

The bushings, sintered and boiled in oil, were installed on the joint near the motor, from here on called “right joint”, and the sintered bushings were installed on the joint near the pump, from here on called “left joint”. A detail with the bushings installed in the two joints is presented in Fig.4.

![Joint with sintered bushing](image1)

![bushing](image2)

![Joint with sintered and boiled in oil bushing](image3)

Fig. 4 The bushing and the joints

a) Joint with sintered bushing; b) bushing; c) Joint with sintered and boiled in oil bushing

The two cardan shaft joints were then installed on the stand and the pump was fixed on the supporting frame to achieve the first inclination angle of the cardan shaft of the range of the ones chosen for trials. As it was previously mentioned, the trials were made for cardan shaft inclination angle of 5°, 10°, 20°, angles obtained by moving the motor and fixing it in the holes on the traverse profiles of the supporting frame. For each inclination, the trial duration on a series was the one presented in Table 1.

The sintered bushings of the cardan shaft’s left joint were greased at the beginning of the trials, both at the starting moment of the stand and during the trials at a period of 8 hours of
functioning according to the technical indication, while the right joint bushings, sintered and boiled in oil, had the necessary lubricant incorporated within their fabrication structure.

Because after 32 hours of trial an increase of the bushings’ temperature at the right joint was observed, it has decided the continuation of the trials after the greasing of the sintered bushings boiled in oil, with the same grease used at the lubrication of the sintered bushings and at the same period of time with these, until a wear appears that would not allow the stand’s functioning.

During the first session of trials (see Table 1) a multifunctional grease based on Li soap type UM 185 Li 3 (LITOL-24) produced by AZMOL Iasi was used, recomended for temperatures between -40\(^\circ\)C and 120\(^\circ\)C, and starting with the second trial session, because the joints’ temperatures increased due to the wears, the special grease Mobil NLG2, produced by MobilOil Company, recomended for temperatures between -40\(^\circ\)C and 190\(^\circ\)C was used. The main characteristics of the greases used for the joints’ lubrication are presented in the Table 2.

**Table 2**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>LITOL-24 UM 185 LI 3</th>
<th>Mobil NLG2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspect</td>
<td>Homogenous, yellow brownish</td>
<td>Homogenous, blue brownish</td>
</tr>
<tr>
<td>Dropping point, (^\circ)C min</td>
<td>185</td>
<td>280</td>
</tr>
<tr>
<td>Penetration index at 25 (^\circ)C</td>
<td>220-250</td>
<td>280</td>
</tr>
<tr>
<td>Viscosity, (^\nu)CSt</td>
<td>8</td>
<td>220</td>
</tr>
</tbody>
</table>

**RESULTS AND DISCUSSIONS**

During trials, the bushings’ temperature was measured after each hour of functioning in the way presented in Fig.5. At the same time, at the ending of the trials in accelerated conditions, the sintered bushings were disassembled, examined and measured to establish the modifications of geometrical parameters as a consequence to the wear phenomenon.

Based on the measurements and on the processing and interpretation of the registered data, the following aspects were noticed:

• Observing the working behavior of the two cardan joints, it was noticed the overheating phenomenon at the joint equipped with sintered bushings boiled in oil, at temperatures up to 85-90\(^\circ\)C, after a working a number of hours representing only 2% of normed duration of working. By greasing on both of the joints with the same lubricant at the same period of time, it was noticed that the joint equipped with sintered bushings boiled in oil entered a normal working thermal condition.

• The type of grease, through its physical-chemical characteristics, influences the working thermal condition of the joints. Thus, according to the diagram presented in Fig. 6., for the same working conditions of the cardan joints, inclination 10\(^\circ\), the grease of type Mobil NLG 2 ensures the functioning in a lower thermal condition.

• After 75% of the established trial period, due to excessive wear, the phenomenon of overheating (96\(^\circ\)C) appeared at the sintered boiled-in-oil bushings, which hadn’t been greased at the beginning of the trials. They were replaced by pin bearings for the carrying out of the trials program.
• The sintered bushings, greased during the entire period of the trials behaved very well the entire time of the trials.
• The following results appeared after the bushings’ disassembling, examining and measuring:
  - Analizing the wear on the external diameter of the sintered boiled-in-oil bushings compared to the sintered bushings, a bigger wear can be observed in the first case, 0.130-0.168 mm compared to 0.099-0.120 mm, due to their functioning without greasing a period of time. As a consequence, these functioned in accelerated condition only 75% of the time established for trials;
  - As for the interior diameter of the bushings (the size of assemblage on the spindle of the cardan cross), the produced wear lead to their ovalization, an alteration of form in the sense of the transmitted moment operation being registered, bigger at the sintered boiled-in-oil bushings, with an average value of 0.12 mm compared to 0.1 mm in the case of the sintered ones;
  - The bushings’ width, no matter of the joint in which they were assembled, did not show significant wear.

CONCLUSIONS

• The lubricant stored in the bushings’ pores as a consequence to their sintering and oil soakage does not ensure the lubricity necessary for their working in normal conditions. It results the necessity of their greasing after every 8 hours of functioning;
• The type of grease, through its physical-chemical characteristics, influences the wear and functioning thermal conditions of the cardan transmission joints. The grease of type Mobil NLG 2 is recommended for the bushings’ lubrication during functioning, type whose dropping point is at the temperature of 280°C.

BIBLIOGRAPHY