5th International Conference
″Computational Mechanics and Virtual Engineering ″
COMEC 2013
24- 25 October 2013, Braşov, Romania

USING AUTOMATIC CONTROL SYSTEMS TO INCREASE DYNAMIC PERFORMANCE AND OPERATING ENERGY PLOUGHING AGGREGATES

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Abstract: *Efficient use of energy and dynamically aggregates formed with tractor on wheels and agricultural machines is a particular problem because it involves a permanent control of the tractor drive parameters such as traction force, depth or width, speed, fuel consumption and if possible slipping. The present study aims to study automatically control opportunities and limiting the slip of the wheels for improving dynamic, operating and energetic parameters by maintaining the traction force to maximum values and fuel consumption to minimum values.*
Keywords: *automatically control, slipping.*

1. GENERALITIES

Higher and continuously increasing fuel prices have led researchers in all areas to make serious efforts to find a way of saving fuel for all types of vehicles. Focused initially on vehicles for transport of persons and goods, is necessary at the moment that also for agricultural tractors. The increase of cultivate areas, full mechanization of many agricultural works and the increasing dimensions of their tractors and agricultural machinery, have led to increasing quantities of fuel for agriculture. Therefore, reducing the specific fuel consumption while increasing operational performance of the agricultural aggregates is a current requirement.

Of the agricultural work, plowing is work that requires the highest specific fuel consumption. Since most agricultural land is plowed in autumn when certain technical and agricultural conditions are fulfilled, tread the soil (stubble) has a relatively low grip. Also once the plow develops high tensile forces that determine frequently the occurrence of slipping with negatives consequences, causing decreased work capacity and increased specific fuel consumption. In addition, if the slip exceeds certain limits, the degradation of rolling surfaces occurs under the action of tire tread wheels. Slipping can occur with other agricultural activities such as aggregates for complex workings and management or transport of organic and chemical fertilizers.

Since the beginning of using worn plows, (Harry Ferguson) found that the charge transfer on the tractor (the vertical component of the resistance force to plowing) increases the adherent load on the drive wheels and its tensile capacity. Subsequently, systems for automatic adjustment for suspension mechanisms led to higher operational performance of plowing aggregates but have not resolved the issue of slipping. Since the 70s (Luth, Zoz, -1972, -1987 Brixius) and also the author with works published (CONAT Braşov 1999 -2000 MIKROCAD-Miskolc Hungary, Russia, Bulgaria 2002) suggested that slipping plays an important role in improving traction and operating performance of tractors and plowing aggregates [2].

2. NEED TO LIMIT THE WHEELS SLIP ON AGRICULTURAL TRACTORS

One of the basic requirements regarding the use of wheeled agricultural tractors to carry out agricultural work and transportation is their operation in an economic regime [3]. As the main component of useful power developed by an agricultural tractor is traction force to analyze its performance it is used the traction diagram. From the traction diagram of a wheeled tractor moving on stubble is observed that slipping occurs mainly when using the gearbox lower levels corresponding to departure from stationary or to heavy agricultural work (Figure 1).

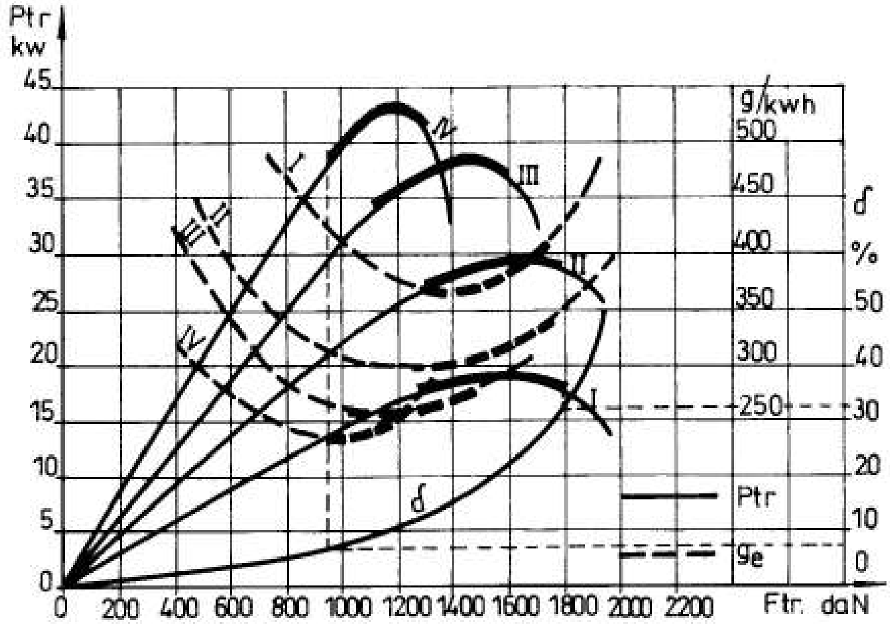

Figure 1: Traction diagram of a tractor on wheel when driving on stubble [1]

In this diagram it can be seen that the tensile strength has maximum values and the specific fuel consumption has minimal values for a slip δ with values the range 10...30%. When these values are exceeded, slipping is very disadvantageous as can be seen in the traction diagram because:
- Increase the specific fuel consumption;
- Decreases the tensile strength;
- Is destroyed the ground surface by the appearance of grooves where water accumulates;
- It destroys soil structure and texture;
- Appears premature wear of tires.

Traction power $\boldsymbol{P_t}$ is given by:

$$P_t = F_t \cdot v_r \quad [W] \tag{1}$$

where, $\boldsymbol{F_t}$ is the tractive force $[N]$
$\boldsymbol{v_r}$ - real speed $[m / s]$
For plowing, global resistance force in plowing is determined by the relationship:

$$F_p = k \cdot a \cdot b \cdot n \tag{2}$$

where $\boldsymbol{k}$ is a global specific resistance coefficient in plowing $[N/m^2]$;
$\boldsymbol{a}$ - deep furrow $[m]$;
$\boldsymbol{b}$ -swath width $[m]$;
$\boldsymbol{n}$ - number of furrow.
By lowering the traction force, the agricultural machine will not work on agro technical parameters imposed, for example, in the plow case, because width and number of bands have constant values, which should decrease working depth.
In the case of a plough, the work capacity is given by:

$$W_p = b \cdot n \cdot v_r \tag{3}$$

It is obvious that the decrease in travel speed will decrease the performance. By limiting the slipping, these disadvantages can be largely eliminated.

3. MEANS AND METHODS OF LIMITING SLIP

For plowing aggregates, increase operational performance by limiting the slip is possible in several ways namely:
- increasing the adhesive load by ballasting;
- using optional locking differentials or auto-locking;
- increasing the adhesive load by charge transfer with SRA force.

The increase of adhesive load by ballasting tractors is one of the best known and used methods today. It has the advantage of being cheap and simple in terms of construction and therefore will not be discussed in this paper.

3.1 USING THE OPTIONAL LOCKING OR AUTOLOCKING DIFFERENTIALS

Optional locking differentials it is used in all wheeled tractors and they are part of the rear axle transmission. Blocking them is required when one of the drive wheels has poor adherence and starts to slip, traction force and speed are decreasing and the tractor tends to stop (100 % slipping) This can be noticed by the operator and therefore he acts the optional differential lock mechanism . By locking the differential, the torque is redistribute to the wheel with better grip, rotating wheels of the tractor becomes synchronous and may exceed this critical condition. Differential lock can be achieved with a mechanical, electromechanical or electro-hydraulic system, controlled by an operator when finds it necessary. The advantage of this method of avoiding / limiting relative slipping is constructive simplicity and low cost price but it has a number of disadvantages:
- attention and additional work for the operator for whom the decision of locking the differential may be subjective;
- difficulty on moving tractor when cornering due to the synchronous movement of wheels;
- increase in specific fuel consumption.

Auto-locking differentials or with increased friction are used for tractors with high pass capacity or forest tractors. They are more expensive than optional locking differentials and therefore rarely used. Another argument is that while working, agricultural tractors shall execute turns with short radius and for this, the rear axle wheels are braked individually until locking. In this case, the presence of self-locking differential as a disadvantage.
Locking of differential is justified only when one of the wheels is slipping. Maintaining the locked state of the differential increases unjustified the specific fuel consumption due to parasitic power movement between the two driving wheels because when they rotate synchronously, due to the fact that they have not the same radius of rolling and the path has not a constant profile, one of the wheels will slip and the other will slide. Researches performed on a plowing aggregate revealed that the use of tractors with 4x4 transmission and optional locking differential is not always enhances the dynamic performance and operating. Tests were performed using a 4x4 tractor with front and rear axle differential optional connected, type U 684 DT. They used in succession the steps 2, 3 and 4 of the gearbox and the gearbox has been engaged to M (medium). Linkage mechanism type was compact, with SRA force and position. The plow used was 3.30 PP type fitted with two or three furrows, with and without support wheel. A part of the results of the tests are shown in Tables 1 and 2.

Table 1: Operating parameters determined on plowing:
Tractor U 684 DT with plough PP - 3.30 M without SRA and with support wheel

Procedure / Parameter measured	2M 4x2 Dif.ulk. 2Tr.	2 M 4x2 Dif.lck. 2Tr.	2M 4x4 Dif.ulk. 2Tr.	2M 4x4 Dif.lck. 2Tr.	2M 4x2 Dif.ulk. 3 Tr.	2M 4x2 Dif.lck. 3 Tr..	3M 4x4 Dif.ulk. 3 Tr.	3M 4x4 Dif.lck. 3 Tr.
1	2	3	4	5	6	7	8	9
Hourly consumption (l/h)	**6.8 – 8.5**	**7.0 – 8.5**	6.7 - 8.5	6.5 – 8.5	-	-	**12.4 -15.7**	**13.5- 16.1**
Work speed (m/h)	4200	4200	4200	4200	4200	4200	6200	6200

Plowing surface (m2/h)	2520	2520	2520	2520	-	-	5580	5580
Productivity (ha/h)	0.252	0.252	0.252	0.252	-	-	0.558	0.558
Minimal consumption; Maximal consumption. (l/ha)	27.0 33.7	27.8 33.7	26.6 33.7	25.8 33.7	- -	- -	22.2 28.1	24.2 28.9
Slipping (%)	4 - 17	4 - 15	1 - 16	0 - 13	35 - 45	25 - 35	15 - 30	14 - 30
Obs.					*	*		

* Sample stopped, slipping over limits.
Tractor type: U 684 DT
Plow type: PP - 3.30 M, equipped with two furrows 2TR, three furrows 3TR and a support wheel;
Monoblock type of linkage of lifting mechanism set to the "floating" (without Automatic Control System).
Significance notations:
Dif. ulk. – differential unlocked;
Dif. lck. – differential locked;
2M, 3M-gear of the gearbox, gearbox coupled to the "medium".
Engine speed during the tests was 2160 rpm. (corresponding to standard rotation of PTO, 540 rpm).
The working depth ranging from 20...25 cm.

3.2. USING THE AUTOMATIC CONTROL SYSTEM SRA FOR FORCE, POSITION OR COMBINED

An automatic control system allows controlling of suspension mechanism through linkage. They can be set to control the power or position. In case of mounted or semi-mounted plows, SRA for force is used and the plows are not equipped with support wheel. Resistance force on plowing is transmitted through the upper link to the force sensor. If the decreased resistance force on plowing to the force sensor level exceeds a certain value, the linkage is operating for removing the plow from the ground. Thus decreases resistance force on plowing and tractor – plow unit can move on. In addition, when it starts the lifting of the plow from the soil, both the weight of the plow and plowing resistance force are transferred to the tractor, which increases the load adhesions and limit the slip. In this regard, Table 2 presents the results of tests carried out with plowing aggregate made of an agricultural tractor U 684 DT equipped with a plow - PP 3.30. For the results to be conclusive, they kept the same conditions and settings for testing.

Table 2: Operating parameters determine on plowing:
U 684 DT tractor, plow PP - 3.30 M SRA whit SRA- Automatic Control System without support wheel

Procedure / Parameter measured	2M 4x2 Dif.ulk. 2Tr	2M 4x2 Dif.lck. 2Tr	2M 4x4 Dif.ulk. 2Tr	2M 4x4 Dif.lck. 2Tr	2M 4x2 Dif.ulk. 3 Tr	2 M 4x2 Dif.lck. 3 Tr..	3M 4x4 Dif.ulk. 3 Tr.	3M 4x4 Dif.lck. 3 Tr.
1	2	3	4	5	6	7	8	9
Hourly consumption (l/h)	**6.7–7.8**	**7.1- 8.0**	**6.1– 7.2**	**6.3- 7.0**	**9.8– 10.5**	**9.7– 10.5**	**13.0 – 15.4**	**13.4 -15.5**
Work speed (m/h)	4200	4200	4200	4200	4200	4200	6200	6200
Plowing surface (m2/h)	2520	2520	2520	2520	3780	3780	5580	5580
Productivity (ha/h)	0.252	0.252	0.252	0.252	0.378	0.378	0.558	0.558

Minimal consumption; Maximal consumption. (l/ha)	26.6 33.7	28.2 31.8	24.2 28.6	25.0 27.8	25.9 27.8	25.7 27.8	23.3 27.6	24.0 27.8
Slipping (%)	6 - 15	5 - 15	1 - 8	1 - 7	16 - 25	15 - 25	10 - 23	9 - 20
Obs.								

* Sample stopped, slip over limits.
Tractor type: U 684 DT
Plow type: PP - 3.30 M, equipped with two furrows 2TR, three furrows 3TR and a support wheel;
Monoblock type of linkage of lifting mechanism set to the "force control" (with Automatic Control System).
Significance notations:
Dif. ulk. – differential unlocked;
Dif. lck. – differential locked;
2M, 3M-gear of the gearbox, gearbox coupled to the "medium".
Engine speed during the tests was 2160 rpm. (corresponding to standard rotation of PTO, 540 rpm.).
The working depth ranging from 20...25 cm.

From the results shown in Tables 1 and 2, it can observe specific fuel consumption increase when the differential is locked, and slipping decrease when using the three points hitch mechanism with Automatic Control System and plow without plow support wheel.

4. CONCLUSIONS

After those presented in Section 3 and in accordance with the values of the parameters in Tables 1 and 2, we can draw several conclusions:

- one of the synthetic performance indicators for plowing aggregates is the specific fuel consumption, if the speed of work during the sample type was kept constant;
- operating with a locked differential rear axle, that decrease the slipping and increase specific fuel consumption (parasitic power circulation between the wheels of the same axis);
- presence of Automatic Control System causes the decrease of slipping by increasing the adherent load on the rear axle.

In conclusion, for increasing the performance of a plowing aggregate, it is necessary to control and limit the wheels slipping by using the following methods:

- optional front axle coupling for tractors 4x4 for avoiding parasitic power movement and kinematic inconsistency between the axis;
- using locked differentials or increased friction under controlled with an automatic control system;
- using of automatic control system for the three points linkage which imitates the slipping and increase the load on rear axis.
- using of plows equipped with force sensor held onto the plow support wheel so that the load on wheel to be minimal, ensuring maximum transfer of load to the rear axis.

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