AUTOMATED DEVICES TO ELIMINATE UNDESIRABLE PERFORMANCE IN MOBILE 4 WD CONSTRUCTION MACHINES

Piotr Dudziński, Kazimierz Pieczonka, Institute of Machine Design and Operation, Technical University of Wrocław

Wybrzeże Wyspiańskiego 27
PL - 50 370 Wrocław, Poland

SUMARRY

The paper discusses two original systems to automaticly eliminate negative behaviours in mobile construction equipment with 4WD.For example in an articulated frame steer machine one of the devices allows for over 2 fold decrease of energy consumption by steering gear.The devices have been designed on the basis of both theoretical analysis and the results of experimental in situ studies on these problems.

Keywords: construction machines, 4WD drive, automation, improving efficiency driving and steering system, decrease of tyre wear

1. INTRODUCTION

In mobile construction machines especially those with the engine power 60 kW,the power is,as a rule,transmitted on to driving axles through driving shafts [1] .Apart from a number of disadvantages in difficult operation conditions, such systems cause some problems connected with the so called kinematic discrepancy in the steering mechanism.Under some operation conditions such discrepancy brings about the circulating power which results, primarily,in additional load on the driving system,the increase of energy loss and more wear of expensive tyres.These phenomena are particularly visible in articulated frame steer construction machines when they are turned at standstill for example,often during loading or unloading processes.The wheels have then considerable slips which is followed by very substantial increase of energy consumption.No SPIN mechanism used in drive axles make the problem even worse [1][2].

2. FOUR WHEEL DRIVE MACHINE RUNNING

In the course of running,a 4WD machine (with the drive axles rigidly coupled) may develop kinematic discrepancy occuring in the driving mechanism The discrepancy results,first of all,from the difference between the displacement of axle wheels dependent on the difference between the kinematic radii (for example different tyre deflection),the difference between the roads the wheels have to trvel along a curve and from the difference in ground formation (uneven surface).The indicator of kinematic discrepancy can be assumed as the ratio of the difference in angular velocities of the pinion in the final drive of differential gear for the rear and front axle (provided the axles are not coupled) to the angular velocity of the pinion in the final drive of differential gear for rear axle.

Fig.1 presents the sensitivity of typical steering systems to kinematic discrepancy [1] .In case of high discrepancy over the surface of high adhesion coefficient,for example concrete,one of the axles may have a positive slip while the other will have a negative one.Both axles will then have opposite moments which means that circulating power has occurred.The exemplary results of in situ studies have been shown in Fig.2 [3] [4] .The growing kinematic discrepancy causes the increase of negative effects resulting from the problem above.High rolling resistances on the road of low adhesion coefficient and high longitudinal flexibility of tyres and ground are conducive to decreasing the difference of moments on the drive axles of the machine.

The usual way to eliminate the undesirable performance in a rigid driving system of mobile construction machines is using the clutch for one of the drive axles to be uncoupled manually by an operator in the course of the transportation travel of the machine.In this solution,however,the decision whether or not it is purposeful to uncouple one of the drive axles is taken,subjectively,by a driver himself and often not carried out in good time.The Institute of Machine Design and Operation,Technical University of Wrocław,has patented the device for automatic uncoupling of one the machine's drive axles in the moment when circulating power appears,and automatic recoupling of the axles with the drive system when the circulating power disappears,Fig.3 [5] .The devices makes use of a certain regularity in the radial or circular displacements of drive shaft's ends.With no circulating power in driving system the displacements in measuring points 7 and 8 have opposite signs.When circulating power appears the displacements have the same signs.

3. ARTICULATED FRAME STEER VEHICLE TURNED AT A STANDSTILL

Articulated frame steering is the only one among the so called geometrical steering systems in common use which,by turning at standstill, allows for easy correction of machine's position during an operation,for example while handling materials.Studies on the performance of articulated frame steer construction machines have proved that turning at standstill is commonly used by operators.Theoretical analyses,however proved that steering resistances at standstill are much higher for articulated frame steer vehicles than for the ones with conventional steering [1].The results of laboratory and in situ studies have shown that the mode of drive axles coupling with driving system has an essential effect on steering resistances of an articulated frame steer vehicle at standstill.For example the turning process of the machine with two conventional drive axles coupled with the driving system turned at standstill will be about 2.5 times more energy consuming than that of the same machine with one drive axle coupled to a driving system,Fig.4 [1] .Apart from that,the studies on the prototypes of articulated frame steer vehicles with No SPIN differential gear in one axle demonstrated that the steering resistances (M_{SR}) increase considerably, making the full turning of the machine at standstill very difficult or altogether impossible because of the limited ability of steering gear to generate disposable moment (DM),Fig.4.

In order to considerably decrease the energy consumption of a turning process at standstill for artuculated frame steer construction machine a device has been patented in the Institute of Machine Design and Operation, Technical University of Wrocław for automatic uncoupling of drive axles when the driving system is off,which has been shown in Fig.5 [6] [7] .

4. RESUME

It is advisable to use simple automatic systems suggested above in mobile construction machines particurly in articulated frame steer ones. The laboratory and in situ tests have demonstrated that such devices make it posible to relieve operator's concentration and improve machine's performance,first of all,through increasing the efficiency of driving system,decreasing costly tyre wear and a very essential decrease (about 2.5 fold of energy loss of a steering gear.

1. Dudziński,P. Vergleich verschiedenen Lenksysteme bei geländegängigen Maschinen mit Radfahrwerken und verschiedenen Antriebsarten. Manuskript der Dissertation B,TU Dresden,1990.

2. Dudziński,P. and Pieczonka,K. The effect of type differential mechanism on steering behaviour of mobile articulated frame steer vehicles. Prace Naukowe Instytutu Konstrukcji i Eksploatacji Maszyn Politechniki Wrocławskiej,No.62,1991.

3. Pieczonka,K. Analytical methods for determining the design and operating parameters for self-propelled machines with articulated frame steering (in Polish). Prace Naukowe Instytutu Konstrukcji i Eksploatacji Maszyn Politechniki Wrocławskiej,No.31,1976.

4. Dudziński,P. Design characteristics of steering systems for mobile wheeled earthmoving equipment. Journal of Terramechanics,Vol.26,No.1,pp.25-82, 1989.

5. Dudziński,P.,Pieczonka,K. and Zięba,J. Selbsttätige Anlage zur Enkupplung der Antriebsachsen. Patent PL Nr.100779.

6. Dudziński,P. Einsatzoptimierung der mobilen Baumaschinen durch die Anwendung der Mikroelektronik. Unveröffentliche Arbeit,Institut für Maschinenwesen im Baubetrieb,Technische Universität Karlsruhe,1985.

7. Dudziński,P. Anlage für die Reifenschlupfbeschränkung im Lenkvorgang eines Fahrzeugs mit Knicklenkung. Patentanmeldung P-279616,1989.

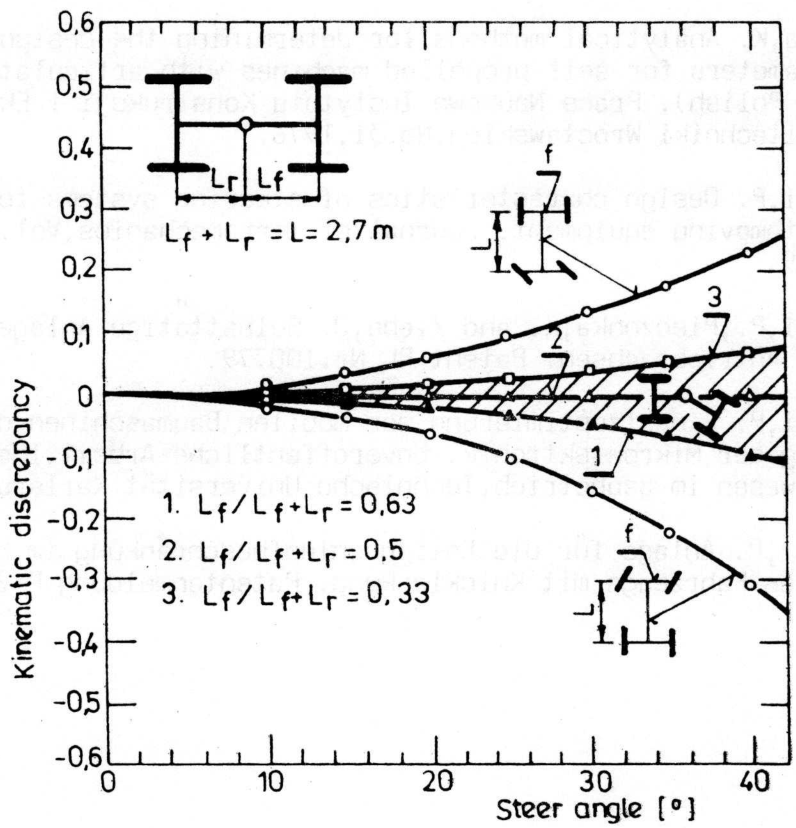

Fig.1. Kinematic discrepancy vs steering angle, the type of steering mode and the location of articulation joint ($L_f/L_f + L_r$) for an articulated frame steer construction machine

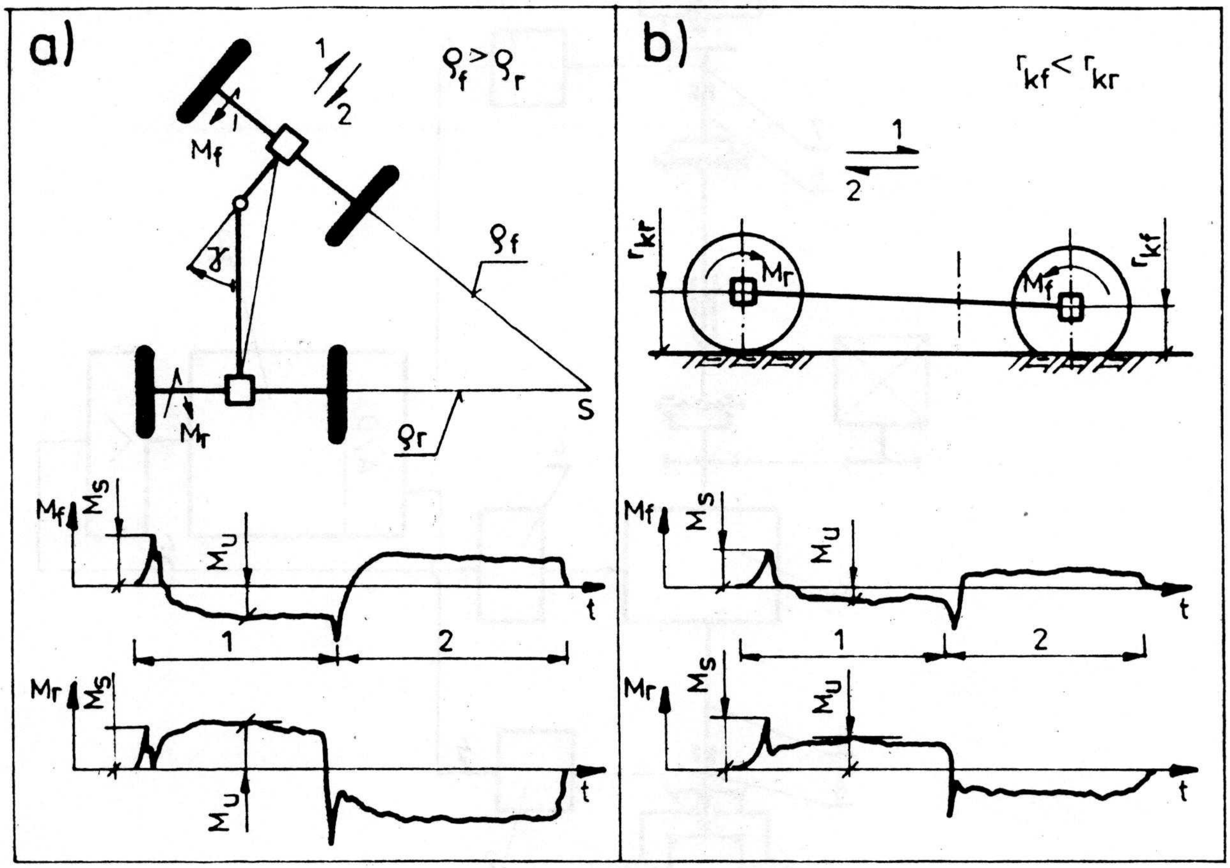

Fig.2. The moments on the halfaxles of an articulated body steer construction machine running on dry concrete:

a) - with maximum articulation angle (γ = 0.7 rad),

b) - straight running (γ = 0), the difference in front and rear wheels radii Δr = 0.03 m, 1 - travelling forwards, 2 - travelling backwards, M_S - starting moments, M_U - moment in fixed motion

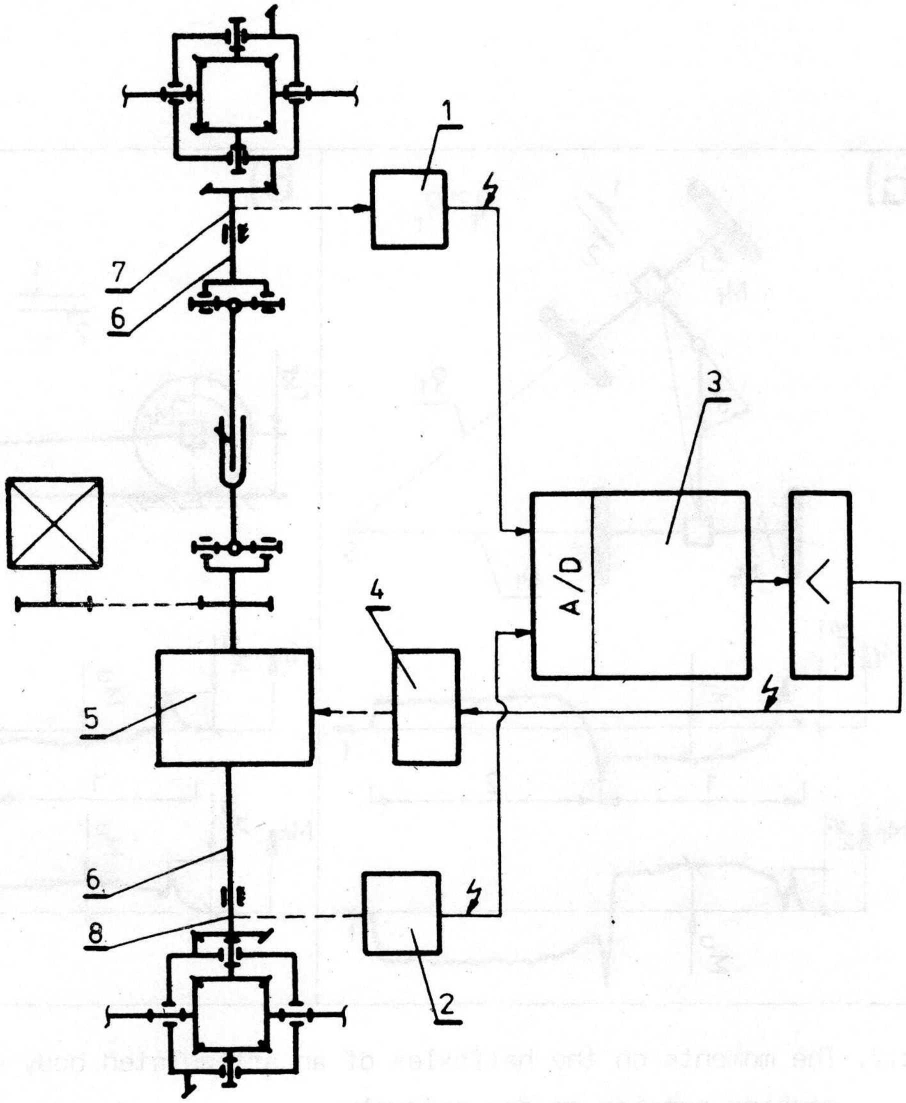

Fig.3. The system for automatic uncoupling of the drive axles in mobile construction machines, 1,2 - displacement sensors, 3 - microprocessor, 4 - electrical control valve, 5 - clutch, 6 - driving shaft, 7,8 - the place where displacements were measured

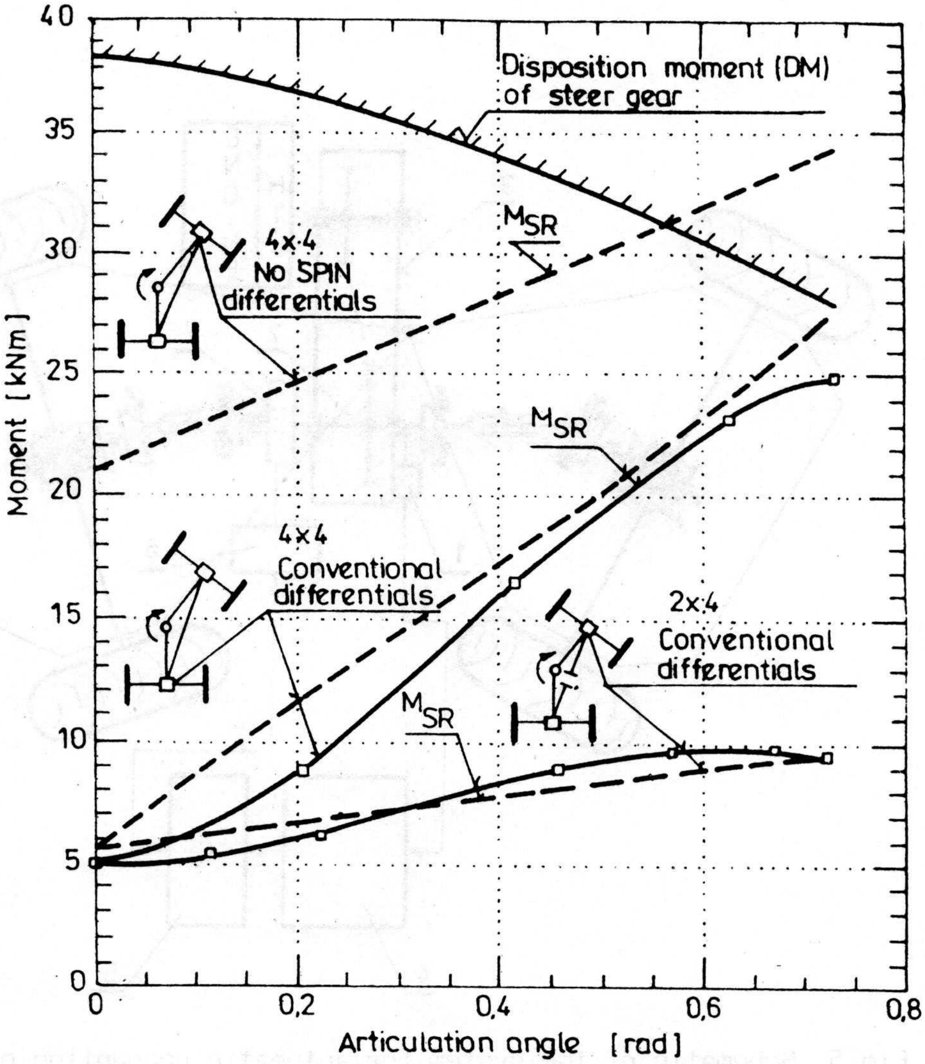

Fig.4. Disposition moment (DM) and steering resistance moments (M_{SR}) on concrete for articulated frame steer loader (total weight of machine 102.5 kN, tyres 17.5-25) vs articulation angle for various of differential gears and axles coupling with driving shaft, ------ calculation, ——— in situ measurements

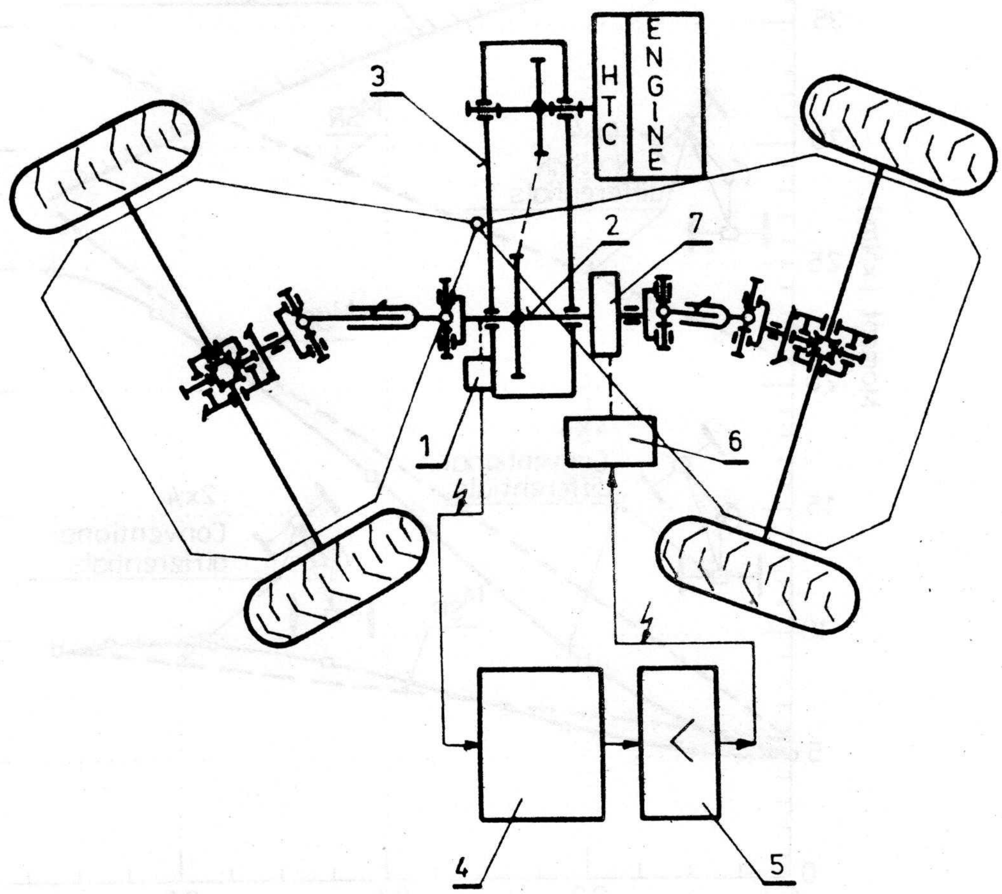

Fig.5. Schematic of the system for automatic uncoupling of driving axles of articulated frame steer machine when it is turned at standstill, HTC - hydraulic torque converter, 1 - rotations sensors, 2 - input shaft of gear box, 4 - rotations indicator, 5 - aamplifier, 6 - electrical control valve