Automatic levelling and wireless control of a mobile hydraulic platform with telescopic crane

Domagoj ANTIĆ, Zvonimir LAŽETA, Željko ŠITUM

Abstract: The mobile hydraulic platform is a device used for providing temporary access to people and/or equipment in inaccessible locations and often at higher altitudes. Crane control is conducted from a work platform, which frequently causes problems since the crane operator disturbs the work of the rest of the staff (in case of movie recording, construction work, etc.). Wires connect the operator console and the operator computers with each other through a telescope, and due to inevitable cable bending there is a frequent presence of expensive malfunctioning. Wiring malfunctioning is directly connected to the crane reliability, so it is of high importance to reduce it to a minimum. In order to increase the system efficacy, the reconstruction of the mobile hydraulic platform, which enables automatic levelling of the work platform and wireless basket control with prevention of capsizing, was designed. The operating program is implemented using the programmable logic controller (PLC), which provides additional system functions implementation.

Keywords: mobile hydraulic platform, telescopic crane, automatic levelling, wireless control

1 Introduction

The mobile hydraulic platform is a device used to provide temporary access to people or equipment in locations which are difficult to access. The malfunctioning of the mobile hydraulic platform was the reason for this proposed project. The mobile platform (shown in *Figure 1*) has had a malfunctioning operating computer, which consequently meant that the platform could not be used. The original control system and the corresponding algorithm were manufactured in the early 90's of the last century, when the platform control was possible only from the basket. The old control system was then replaced with a PLC device (Siemens S7-1200 version). As for the original functions, not only were they restored, but new functions were built in as well. By incorporating a biaxial inclinometer, automatic levelling of the platform undercarriage was enabled, while building in a wireless module made it possible to manage the crane from an arbitrary location. Lastly, by designing a new operating algorithm (together with the existing sensory evaluation) a higher level of safety was achieved.

Domagoj Antić, mag. ing. mech., Zvonimir Lažeta, mag. ing. mech., Ph.D. Željko Šitum, full professor, all University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture

2 Control system before reconstruction process

The control of mobile hydraulic working platforms can be mechanical or electrical. One form of mechanical control is the indirect control in which one uses a control

Figure 1. *Mobile hydraulic platform Wumag WT 225*

Figure 2. *Cabinet for levelling process and main distribution cabinet before reconstruction*

stick of the intermediate 4/3 valve to control the stroke of the main proportional valve and achieves the movement of a specific actuator. Another form of mechanical control is the usage of steel ropes. One side of the steel rope is tied to the control stick, while the other one is tied to the proportional valve. The advantage of mechanical control is a stronger robustness than with the electrical one, and the disadvantage is the lack of process automatization. The other form of platform control is electrical control, meaning that potentiometers, which measure the deflection of the stick, were built into the control stick, the signal from the potentiometer being transported via cable to the PLC. The operating computer, dependent on the stick deflection, sends out a signal (PWM) to the proportional solenoid which moves the valve spool. The advantages of this kind of control are: a more precise actuator moving speed control (in comparison to the mechanical one), the possibility of process automatization, etc. The disadvantage is the potentiometer contact drift, which makes it necessary to recalibrate the system.

The work platform under consideration was manufactured by Wumag (model: WT 225) and it is placed on the Mercedes-Benz 811 model. The platform was the first model in which the mechanical control of the distributor was replaced by the electrical control system (*see Figure 2*), and the transition to the latter was accompanied by certain problems. For example: upon ceasing to apply commands to the control stick, the platform continues to move for approximately two seconds, which is extremely dangerous if one is working close to an obstacle. In addition, during work the computer loses the information on the current position of the platform (in space), which makes it impossible for the platform to continue to operate. The consequence is that the platform (and the staff on the platform) remains at this height until a licensed operator arrives and manually lowers the platform to the transport position. All these reasons indicate that the problem lies within the operating computer and/or the operating program. The factory computer cannot be accessed due to its specific manufacturing and programming, so another solution needed to be found in order to remove the aforementioned difficulties.

3 Reconstruction process of the mobile hydraulic platform

- ***Automatic levelling of the hydraulic platform***

In the old process the levelling of the truck was done manually: the operator controlled every stabilizer individually using the handles of mechanically activated distributors and the inclination of the truck was monitored via a circular libelle (bubble level).

In the new process the levelling will be done automatically: the operator will have at his or her disposal two buttons for levelling activation or returning the platform to a transport position. In concordance with the operator's choice, a specific algorithm will be activated within the PLC and the desired activity will be performed. In order to achieve automatic levelling, instead of distributors with manual activation, classical distributors with mechanical and electrical activation will be built in (*Figure 3*). The mechanical activation of the distributors next to the electrical activation, serves as an alternative if the electrical activation fails. The measuring element which serves as the recurrent connection of the desired operating algorithm is a biaxial inclinometer placed in the area of the undercarriage of the truck.

The goal of the automatic levelling process is to bring both of the angles within the ±0,3° area. In the case of manual levelling the accuracy that could be achieved was ±1° which is three times worse. One controls the stabilizer pullout speed, and regulates the two angles of the shift. The additional mitigating circumstance is that the pullout speed is low in comparison to the distance of the stabilizers. Furthermore, regarding the minimal exchange of the hydraulic components, one should take into consideration the limitations imposed on us with this hydraulic setup: the flow on each of the stabilizers has not been defined;

Figure 3. *Cabinet for automatic levelling after reconstruction procedure, hidraulic distributors for nivelation process and circular libelle*

instead, one is dealing with a single flow (as well as the pressure). It is necessary to prevent stabilizer separation from the bottom. With manual operating it is quite common for the truck "to be left" with only 3 stabilizers (instead of 4) due to the fact that the operators activate one stabilizer at a time. The electrical distributors are in the classical process, which presents a significant limitation. Due to the possibility of placing the spool in end positions exclusively, the regulator reference must be of binary nature (0 or 1). Physically the logical signal manifests itself as a 0V or 24V charge. If the regulator output must be logical, then the regulator will have to be logical as well.

- ***Wireless control of the hydraulic platform with telescopic crane***

The reconstruction of the work platform is based on the electrical installation add-on, replacement of the operating computer and the implementation of wireless control. With the rental function of the platform for movie recording, large commercial posters replacement, placement of the antenna posts, construction work on residential buildings and all other activities in which the operator in a basket is obsolete, it is necessary to implement a wireless operating platform in order to control the system outside the basket. It is worth mentioning that the wireless control eliminated the cyclical need of the telescope cables replacement (which is a part of the maintenance plan), and the cost of this work was worth thousands of euros.

Figure 4. *Main distribution cabinet after reconstruction procedure*

In the process of reconstruction the following equipment was built in (*Figure 4*):

- PLC device (Siemens S7-1200, model 1217),
- SCALANCE transmitter and receiver,
- Charge stabilizer,
- Analogue input modules,
- Digital input and output modules,
- Power amplifiers (for PWM outputs),
- Relays,
- The operating console and elements for the activation of individual functions.

The basket control requires previous successful work platform levelling. The operator primarily moves away/lifts the crane telescope from the saddle plates in order to prevent the collision of the saddle plates and the telescope, since the rotation of the telescope while

it is mounted on the saddle plate, results in its breakage. The rotation of the work platform is program-disabled until the telescope leaves the saddle plate. The information on the telescope position is provided by the inclination sensor (single-axis inclinometer) which is built into the telescope platforms. After the platform has left the air space of the saddle plate, the operator has all of the work platform manipulation functions at his or her disposal. In other words, the operator can by choice pull out the platform, lift it or rotate it. Apart from the inclination telescope sensor, the work platform has four other pressure sensors which measure the pressure of the oil in the hydraulic cylinder for lifting and lowering the work platform telescope. The two sensors measure the pressure in the chamber for the cylinder pullout, and the other two sensors measure the pressure in the chamber for the cylinder retraction. Every chamber also has extra sensors in case one of the sensors from any of the previously mentioned sensor groups malfunctions. In this way the system can continue to function with a warning that some repair is necessary. The pressure sensors are necessary because they detect which force is appearing on the cylinder piston. Together with the information provided by the telescope inclination sensors and the pressure sensors in the telescope lift cylinder, it is necessary to program the anti-capsizing protection of the work platform. Points in space are defined with the help of experimental measuring, which are then used to construct a curve which is identical to the one defined by the manufacturer in the work diagrams. The work diagram is the graphic depiction of the space in which the movement of the work platform is allowed. When the operator brings the platform to the edge of the work space, the anti-capsizing protection is activated, meaning further pullout and the lowering of the telescope are disabled and the yellow light on the operating console is turned on, signalizing the border position of the work platform. rotation is enabled because it does not affect the stability of the work platform. The light turns on in order to inform the operator that further work is not possible, that is, further distancing from the undercarriage is not possible. Alongside this form of protection, there is the telescope impact protection in the cabin of the vehicle. On the work platform flange there are two micro-switches which detect whether the telescope is close to the cabin. If one of the micro-switches is activated, this symbolizes the lateral access to the cabin of the vehicle, and if both are activated this means that the work platform is above the cabin. Should the operator press the control stick to lower the telescope of the work platform onto the cabin of the vehicle, the algorithm will prevent any further descend. With the aforementioned protection, there is also the type of protection which disables the impact of the basket against the telescope of the work platform, that is, if the inclination is less than 15˚ the rotation of the basket is disabled. If it were not so, the basket would then hit the work platform telescope. If the basket is not in the central position, and the operator wishes to lower the work platform telescope under 15˚, a green light turns on on the operating console, and further lowering is not possible until the basket's initial position is restored. The blinking notifies the operator that the basket is not in the central position. Furthermore, on the operating console there are buttons for turning the internal combustion engine (ICE) on and off. Of course, there is an impact switch added to the console (called "the mushroom") which is activated by the operator in case of an accident. By activating the impact switch, the ICE shuts down and all of the PLC outputs are deactivated. The operating console for the remote control of the mobile hydraulic platform is shown in *Figure 5*.

Figure 5. *Operating console for the remote control of the mobile hydraulic platform*

4 Mobile hydraulic platform demonstration

A good way to gain insight into the demonstration mode is to watch the recording at the following URL: *https://www.youtube.com/watch?v=8djCEq4THiY&feature=youtu.be* in which the functionality and the actual behaviour of the entire crane are observable. The video shows the automatic levelling, and later on the manipulation of the work platform using wireless communication.

5 Conclusion

The automatic levelling facilitates the usage of the crane and raises its productivity levels. The advantage of automatic levelling is an algorithm which enables the use of classical distributors with electromagnets instead of very expensive proportional distributors. The choice for this particular process of automatic levelling was closely connected to the objective of easier implementation regarding cranes/tracked vehicles of other dimensions. After installation of standard equipment, maintenance of the

work platform is simplified, which significantly reduces exploitation costs. If someone wants to install a new function into the process, it is now easier because of the achieved modularity and software standardization. The next step in the development of this project is the operation of the platform with external coordinates. In the regime of working with external coordinates, the operator would use the control sticks to define the moving speed. Furthermore, there is a possibility for the operator to memorize a specific position in space by clicking on a button, and if he or she should wish to return to this position, they would just have to press the button and the platform would be returned to that particular position. In addition, a function for restoring the telescope in the transport position (saddle plate) can be built in.

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Information about authors:

Domagoj Antić, mag. ing. mech.,
Zvonimir Lažeta, mag. ing. mech.,
Ph.D. Željko Šitum, full professor.
University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture
Ivana Lučića 5, 10000 Zagreb, Croatia

Avtomatsko niveliranje in brezžično krmiljenje mobilne hidravlične platforme s teleskopskim dvigalom

Izvleček: Mobilna hidravlična platforma je naprava namenjena začasnemu dviganju oseb in opreme na nedostopna mesta, pogosto visoko nad tlemi. Običajno se z dvigalom opravlja iz delovne platforme s strani pooblaščenega operaterja, kar je večkrat problem, ker mora operater hkrati opravljati še delo drugih oseb (npr. snemanje filmov, dela v mestih, ...). Z vidika vzdrževanja platforme se pogosto pojavljajo tudi poškodbe ožičenja, ki je napeljano skozi teleskop hidravličnega dvigala. Poškodbe ožičenja v veliki meri vplivajo na razpoložljivost dvigala, zato je želja, da je verjetnost njihovega pojava čim manjša. Z željo po povečanju učinkovitosti sistema je bila izvedena rekonstrukcija hidravlične dvižne platforme z avtomatskih niveliranjem in brezžičnim krmiljenjem, ki hkrati onemogoča prevrnitev. Za PLC krmilnik je bil izdelan program, ki omogoča še dodatne prednosti takega sistema.

Ključne besede: mobilna hidravlična platforma, teleskopsko dvigalo, avtomatsko niveliranje, brezžično krmiljenje

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