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Prototype System for Gas Tanks Cleaning

Zoran Petrović[1*], Uglješa Bugarić[2], Dušan Petrović[2], Miroljub Babić[3]
[1]Tecon Sistem d.o.o, Belgrade (Serbia)
[2]Faculty of Mechanical Engineering/Department of Industrial engineering, University of Belgrade, Belgrade (Serbia)
[3]Makpetrol d.o.o, Belgrade (Serbia)

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1. INTRODUCTION

Contemporary usage of LPG in Serbia and Macedonia, in the house holds, or in process of food preparation, in food industry is mainly focused on usage of the gas in the steel tanks. Capacity of the tanks that are most common in use are: 2 kg, 3 kg, 5 kg and 10 kg. Gas tanks with capacity of 2 and 3 kg are usually used for mobile applications (usually for camping, outdoor food preparation, etc.), while 5 and 10 kg gas tanks are usually used in households and food preparation in food industry sector.

Refiling of the gas tanks is one of the main business activities in gas sales process.

Information provided by investor is that 90% of the refilling is covering gas tanks weighted 5 kg and 10 kgs. One of the main problems in refilling of the gas tanks is that they are in time covered by dust, or organic and/or nonorganic dirt which is causing two main problems.

First one is covering safety issues, since residual dust and dirt on gas tanks can, in contact with elements of conveying system, cause sparks, which can then cause explosion, since environment in the filing facility is considered as potentially very explosive.

Second problem is with retention of the gas tanks, since customers are avoiding to buy dirty tanks and they are staying in the warehouse for indefinite time, making additional cost for keeping them on stock.

In order to solve this problem, prototype of conveyor which is driving gas tanks through washing and drying modules is made.

Gas tanks washing process has two main aspects that were considered.

First one is referring to quality of the wash, which depends on the Siner's circle. [1]

Second problem was the design of conveyer which was conveying gas tanks through washing and drying modules.

2. SINERS CIRCLE OF WASH

For quality wash there are 4 interconnecting factors, known as „Siner Circle" – simple formula for cleaning cycle of any cleaning operation (Figure 1).

2.1. Mechanical action

First factor is mechanical action, which is removing dirt by application of mechanical force. Mechanical force that can be used in washing cycle has its limit, since excessive use of the force can produce damage to the washed surface as result of excessive wear and potentially explosion since system is working in hazardous environment.

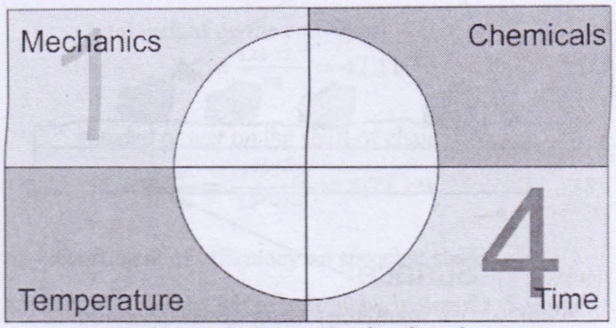

Figure 1: Siners Circle of wash

2.2. Chemical action

Chemical action is defined as usage of cleaning agents in the cleaning cycle. Choice of right cleaning agent is essential for wash quality, along with economics of washing process. Use of chemical agent with optimal dosage of chemicals is only way to obtain optimum results without damaging surfaces, or influencing environmental pollution.

2.3. Temperature

Depending of the type of washing circle, temperature has different influence. For any kind of wash in which surfaces are covered with grease or oil, washing temperatures have significant influence. Like with all other cleaning factors, excessive usage of high temperatures can damage washing surface and also damage equipment.

2.4. Time

Time is one of the crucial factors, since longer washing cycles are giving better results. Washing time depends on the surface type to be cleaned, the dirt which has built-up and the chemical agents used.

3. DESIGN OF THE SYSTEM

Investor demand was that complete system for gas tanks cleaning, should be added to existing gas filing line. Gas tanks that should be washed should include standard tanks net weight 10 kg and 5 kg. Capacity of the system should be 400-500 gas tanks per hour. Extension should be with the same elements as existing one in order to provide complete unification of spare parts. System should be modular and consist of 3 washing and drying modules.

*Corresponding author: Antifašističke borbe 21 b, zoran.petrovic@tecon.rs

3.1. First module – spraying of the chemicals

First module should provide distribution and spraying of dissolved chemical agent with hot water in order to better penetrate into the dirt on the surface of gas tanks. Chemicals should provide strong adhesion of the molecules of chemical agent to form layer on the surface of gas tanks, in order to move residual dirt on top of the layer (Figure 2). Regarding Siner's circle, in the first module, temperature of the water along with right choice of chemicals are providing optimal results in moving residual dirt above layer of chemicals.

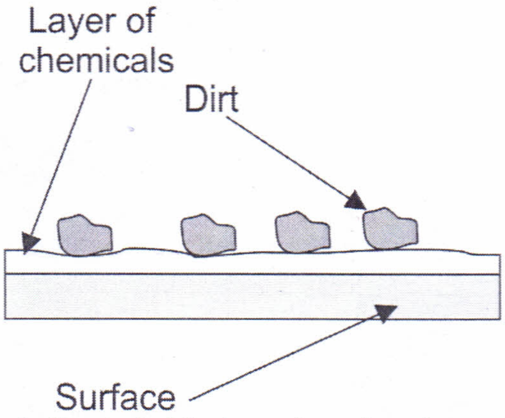

Figure 2: Chemical addhesion to the surface of gas tanks

3.2. Second module – rinsing and applying drying agent

Second module should provide rinsing of the gas tanks, with hot and cold water in order to remove chemicals along with dirt from cylinder surface.

Two systems for rinsing will be used.

First one is with hot water with temperature up to 60°C on high pressure of 150 bar in order to provide enough mechanical action to clean residual dirt.

Second one is with cold water, sprayed in low pressure up to 10 bar in order to remove residual chemicals and cool down gas tanks before conveying them to filling station.

On the exit side of the module, there is chemical drying agent spraying system. Chemical drying agent has similar role as chemicals in the washing process. Since chemical agent has the form of anion, when applied, water drops are pushed to the top of the surface layer, which makes easier to remove them with air blow system. Second role of drying agent is levelling surface of the tanks which have micro abrasions (Figure 3).

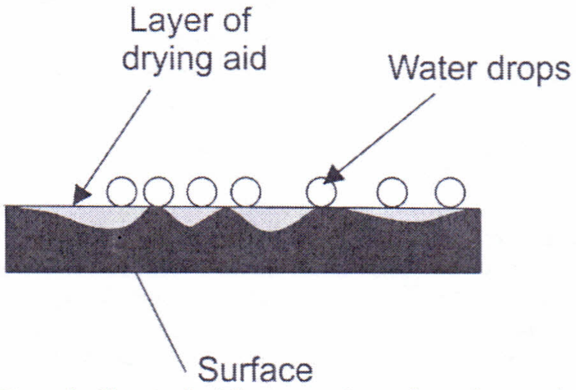

Figure3: Chemical addhesion to the surface of gas tanks

This way air stream is flowing with less turbulences which effects quality of drying. Also, layer of drying agent resides on the surface of the gas tanks, which has the role of protective film against corrosion and protects gas tanks of excessive dirt while in usage. When gas tanks come to refilling, they are cleaned much easier then first time. Picture of drying agent moving water drops above the layer is given of Figure 4.

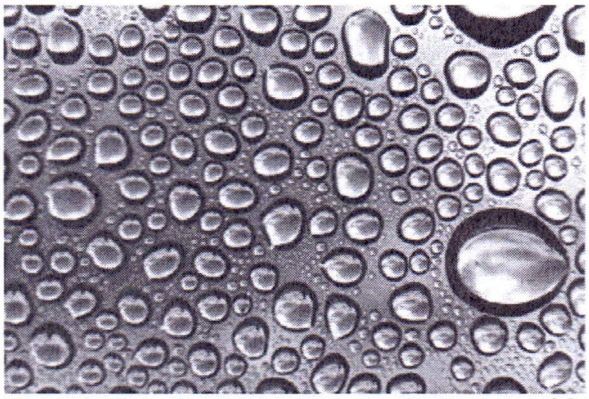

Figure 4: Drying agent moving water drops on top of the layer

3.3. Third module – drying of the gas tanks

Third module should provide removing of the water from gas cylinder surface with side and top air blowers. One explosion proof motor of 3 kW power and 1200m³/h of air flow is used in order to blow water drops from surface of gas cylinders.

4. CONVEYOR FOR GAS TANKS

Conveyer is designed in order to provide maximum capacity for filling up to 500 gas tanks per hour.

Speed of conveyor:

$$v_{con} = \frac{500}{60} = 8{,}33 \frac{m}{min} \qquad (1)$$

Diameter of 10 kg tank is 300 mm, so there are 3 gas tanks in 1 meter conveyor length.

In order to provide flexible speed of conveyor, frequency regulator is chosen for regulating speed of the conveyor.

In order to provide optimum cleaning and drying results, technological parameters that must be followed are:

- minimum elapsed time from applying washing chemicals to rinsing: 1 min.
- minimum elapsed time from applying drying aid chemicals to air drying: 1 min.

When putting those two restrictive conditions together, minimal length of conveyor should be 16,66 m.

In order to follow up complete process of taking empty gas tanks from outside storage, length of conveyor must be prolonged.

With entry and connection point defined, one more technical aspect of the system was important for complete defining of the conveyor track and that is minimal radius of the curve of the conveyor.

According to information provided by chain producer, minimal radius of the curve has to be 1000 mm in order that chain doesn't stuck on the curve section.

Also, entry point of the conveyor is defined by investor in order to provide enough space on the outside storage.

Since one of the main aims of the conveyor is to connect outside storage with existing conveyor, length after last, third module (drying) is enlarged in order to provide connection for existing conveyor.

Disposition of the complete conveyor is given on the Figure 5.

4.1. Calculation of chain tension force

Calculation of chain tension force (empty conveyor) [2]:

$$F_o = 1{,}05 \cdot [F_{min} + g \cdot (\omega \cdot q_M \cdot L_h^{RO} + 2\omega q_{tr} L_h \pm q_M \cdot H) + W_o + W_{PL}] = 12275 \text{ N} \quad (2)$$

Calculation of chain tension force:

$$F_o^e = 1{,}05 \cdot [F_{min} + g \cdot (2\omega q_{tr} L_h \pm q_M \cdot H) + W_o + W_{PL}] = 6521{,}7 \text{ N} \quad (3)$$

ω – friction coefficient of chain, ω = 0,55. Coefficient is increased 50% from one stated in the table (0,3-0,35), since conveyor is working on outside temperatures with possibility of frost in the driving channel of conveyor.

q_M – weight of the transported material, q_M = 42 kg/m

L_h^{RO}- length of horizontal projection of pulling section of chain conveyor, L_h^{RO}=38 m

q_{tr}- weight of driving mechanism of conveyor (weight of the chain), q_{tr}= 16 kg/m

L_h- length of horizontal projection of conveyor, $L_h = 38\ m$

H – lifting height of conveyor

W_o- fricion force on the side of driving conveyor chanel,

$$W_o = 10^{-3} \cdot \mu h^2 \rho g l_b \quad (4)$$

$W_o = 0$, gas tanks are not touching side channels

μ =0,5-0,8 – friction coefficient cast iron on steel

$W_{PL} = 0$ - friction force of plowing mechanizam on the conveyor end.

Minimal driving force is calculated: as [3]:

$$F_{min} = 6000B + 40L = 6000 \cdot 0{,}086 + 40 \cdot 38 = 2036\ N \quad (5)$$

B – width of driving plate surface, or in this case double width of the chain

L – length of the conveyor, L = 38 m

$$B = 2 \cdot 0{,}043 = 0{,}086\ m \quad (6)$$

Maximal number of gas tanks on the conveyor: 126 tanks.

Weight of the empty gas tank = 12,7 kg

Total weight on the conveyor

$$q_M = \frac{126 \cdot 12{,}7}{38} = 42{,}11\ \frac{kg}{m} \quad (7)$$

Needed power on the shaft of chain sprocket:

$$P_o = \frac{F_o \cdot v}{10^3 \eta_v} = \frac{11705 \cdot \frac{8{,}33}{60}}{10^3 \cdot 0{,}95} = 1{,}71 \text{ kW} \quad (8)$$

η_v – coefficient of efficiency on sprocket shaft.

Power of electro motor (minimal):

$$P_o = \frac{P_o}{\eta_{meh}} = \frac{1{,}71}{0{,}94} = 1{,}82 \text{ kW} \quad (9)$$

η_{meh} - coefficient of efficiency of gearbox.

Torque on the chain sprocket (empty conveyor):

$$T^e = \frac{D}{2} \cdot F_o^e = 978{,}25\ Nm \quad (10)$$

Where diameter of the sprocket is:

D = 300 mm

Motor chosen for this application has following characteristics: Nominal power: 3 kW Emerson, gearbox with transmission ratio i=103, with nominal torque M= 1900 Nm.

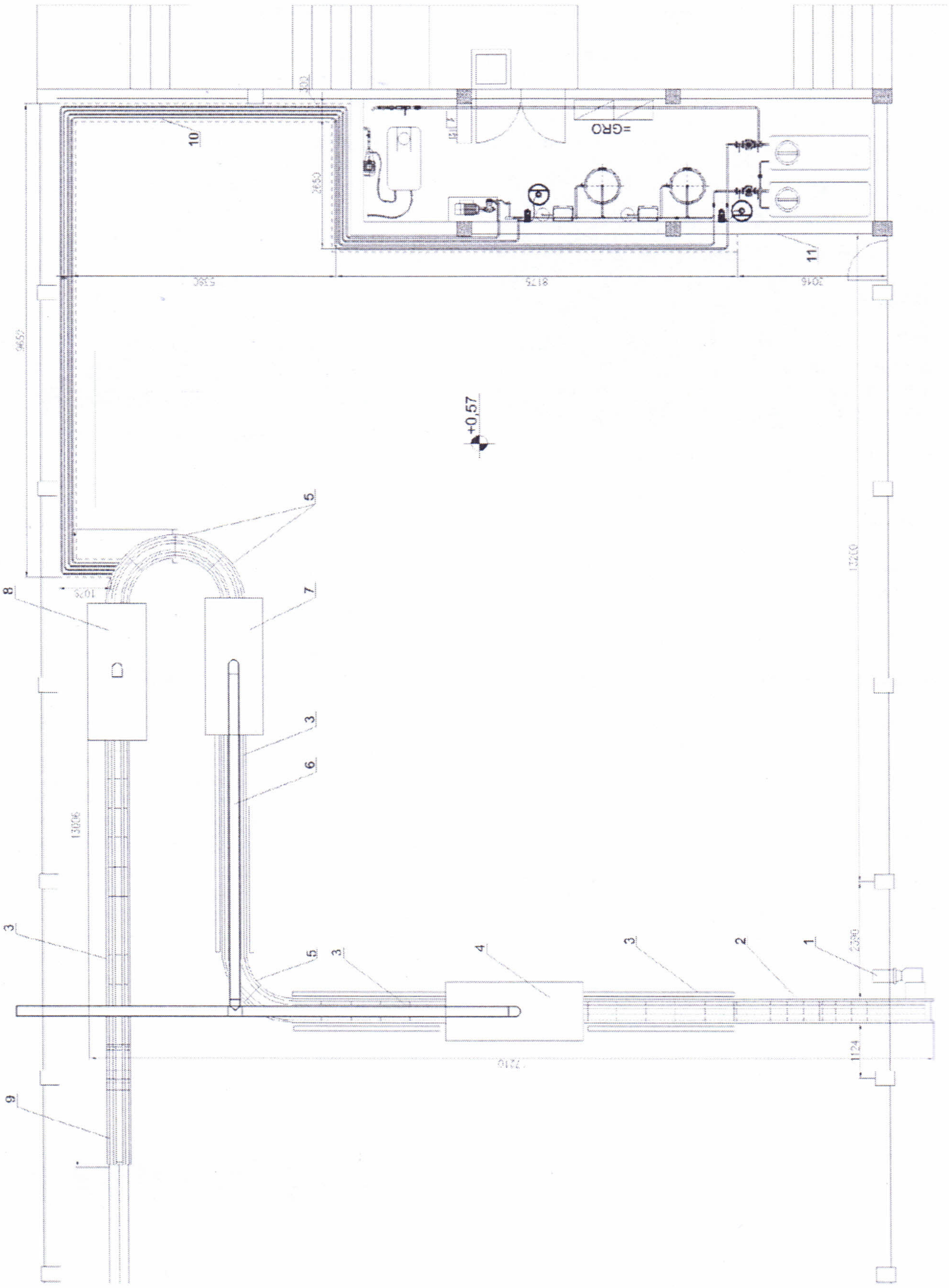

Figure 5: Disposition of the system in the hall

Elements of the system (Figure 5):

1. Motor for conveyor
2. Input conveyor module
3. Standard conveyor module
4. Module for chemical spraying
5. Curved module
6. Adjustment module
7. Module for rinsing and drying aid spraying
8. Module for drying
9. Connecting module
10. Channel for connection hoses
11. Technical room for equipment

Connection of the motor and sprocket can be seen on the Figure 6.

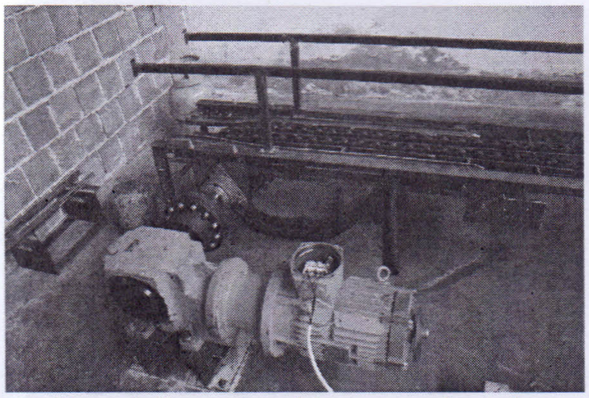

Figure 6: Connection of the motor and sprocket

Calculated torque was verified during the testing phase, with empty conveyer. Since motor of the conveyer is connected to the frequency inverter, torque can be read in real time on the display as percentage of the motor maximum torque.

Measured torque was going from the 67% at the start of the motor, to 49,99% in nominal working regime (Figure 7).

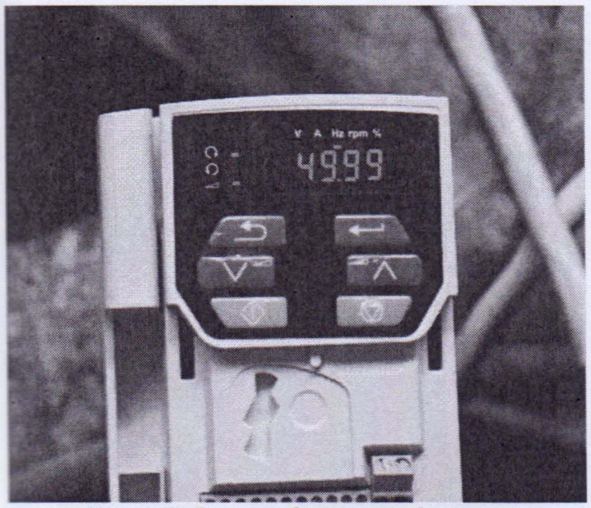

Figure 7: Generated torque on the motor

Calculated relation between torque on chain sprocket on empty conveyor and maximum torque can be measured by frequency inverter:

$$e = \frac{T^e}{T_{mot}^{max}} = \frac{978{,}25}{1900} = 0{,}51 \qquad (11)$$

5. CONCLUSION

Prototype design is always heavy task, specially when it includes different research fields.

In this case, first field that was explored was filed of industrial cleaning.

This field, from methodology point of view in in lack of published articles for different industrial applications. For that reason, general approach, which is given through Siner's circle was used. This approach doesn't give quantitative analyses for washing quality, it rather gives recommendations of most important factors for satisfying cleaning results.

Relation between Mechanical work, Chemicals – agents and consumptions, Temperature of wash and Time elapsed for washing are giving optimal washing results. For mentioned application, some factors were limited due to the technical, , safety, and/or environmental issues.

Mechanical force used in this application was focused on the water flow and pressure through nozzles in order to follow restriction on usage of friction in hazardous areas.

Chemical action was limited on usage and dosage of the chemicals used in the washing process.

Temperature used is limited to the maximum operating temperature of the both centrifugal and piston pumps. For centrifugal pumps this temperature is rather low, while temperatures on the high pressure piston pumps can go up to 60°C.

Last factor – time is also limited by defined capacity of the system. Since demanded capacity of the conveyor was 500 gas tanks/hour, speed of the conveyor is at least 8,33 m/min. This means that gas tanks must have satisfactory cleaning results conveying through the system with mentioned speed.

With all mentioned restrictions, mechanical force is limited to pressure wash, temperature with maximum temperature that equipment can bare, time with demanding capacity, only type of chemicals and dosage can be changed in the cleaning process. This leeds to much more simple choice in the design of the system, having really only one variable.

All mentioned above and washing technology, determined design of the washing system with 3 modules, which includes: module for chemical spraying, module for rinsing of chemicals along with residual dirt and drying module.

Calculation of the conveyor was based on some assumptions for the straight line conveyor with some coefficient enlarged. Calculation was made based on the assumption that system is working on outside temperatures, with high friction coefficient. After measuring torque on the frequency inverter results were very close to calculated ones.

Obviously, high friction coefficients for the low temperatures of the surrounding in which conveyer is working, covered fraction of the curved elements of the conveyor, but this can be the problem for complex conveyor paths, with curves. In order to closer describe mentioned problem, further research will be done. There are some papers on this subject written by Sumpf, Bankwitz and Nendel and Rasch [4], but they covered only special plastic multiflex chains in their work.

Further research of the authors will be in this field, in order to get more accurate calculation of the reaction forces of complex conveyors.

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