a gear, installation, computer validation system

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COMPUTER-AIDED PROJECT OF THE PROGRESSIVE GEARS INSTALLATION VALIDATION WORKSTATION

Abstract

In reply to the Polish market demand and the increase of competitiveness in the lifting sector the innovative construction of CHP 2000 type gear with changeable loading capacity configuration has been created. Computer-aided project of the workstation to validate the installation of a friction lift brake (the gear) in the production conditions is presented in the research study. The construction and the operation scheme of the lift braking system are described. Methodology of validation has been proposed at the stage of production on the basis of variability of the production demand for the presented model of the progressive gear.

1. INTRODUCTION

Presently, the professional literature regarding the aspects of the construction and operation of the braking systems and progressive gears does not focus much on that subject matter. In the publication [11] the authors touch the aspects connected with the impact of the wires weight, the wires which supply the lift cabin with power, as well as the carrying lines in the so called tall lifts working in tall over 40 floors buildings on the lift operation. In such lifts, a significant height of lifting is connected with the fact that it is necessary to use a leveling belt which compensates the weight of carrying lines and the power supply wires and in consequence the remaining subassys of the lift are not excessively loaded. The authors describe in a model way the behaviour of the leveling belt and the impact of the belt on the linear model of the lift operation. Moreover, they test the impact of the leveling belt horizontal dislocations on the system self-vibrations frequencies. The authors in the publication [2] deal with the aspects regarding

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the application of a reduction method to evaluate the lift operation dynamics. In the presented analyses the lift cabin model has been reduced to a flat system with one, vertical level of freedom. The authors used the presented reduction methodology to describe a specific mechanism of a cargo lift by describing the presented aspects in a mathematical way. Furthermore, the authors in their research study analyse what kind of results, parameters of the lift operation have the impact on the lift system accelerations characteristics.

In the publication [10] the authors focus on the aspects connected with the application of neuronal nets to analyze the lift operation vibrations due to the variable weight of the load which is carried. The applied neuronal nets were used by the authors to assess the vibrations symptoms as a result of which a part of the lift or the whole device damage could be detected. In the publications [1, 7] the authors describe the application of a finite elements method to evaluate the stiffness and resistance of the cabin frames construction in different types of the lifts also including the gears. The application of FEM method in the described aspects was used by the authors to optimize the carrying frame construction in the light of the frame construction section beams, to reduce its weight, to determine safety coefficients and on the basis of received results they made an attempt to determine places of the lift frame system which are sensitive to damage. The issues connected with the lift braking system dynamics, the analysis of applied materials influencing the comfort of operation as well as with the gears are touched also in the research studies [3, 4, 5, 6]. In those publications the authors focus among others on the braking system analysis. They compare the European manufacturers' gears construction and operation with the newly developed solution.

While analyzing the state of the existing knowledge regarding the subject matter the lack of information can be noticed especially in the international publications. Moreover, there is a shortage of research studies referring to the application of computer systems to aid the gears production processes as well as the systems supporting the supervision over the gears operation.

With respect to the increasing market demand for the progressive gears in different types of settings and in different quantities dependent on the market demand variability, it becomes purposeful to undertake the aspect regarding the application of the systems aiding the installation processes in the production facility. The variable configuration of the applied packets of Belleville springs requires constant monitoring of the proper gears installation what in the further operation of the lifting device is reflected in the proper operation and their reliability.

2. CONSTRUCTION AND OPERATION OF THE PROGRESSIVE GEAR

Recently developed construction of CHP 2000 type progressive gears was designed in order to be applied in the lifts with the nominal loading capacity from 8000 up to 20000 N, what constitutes approximately 75% of devices manufactured on the national market. Estimated yearly production of this type of gears with variable braking construction would be closed in the number of 2000 shipsets per year. Fig. 1 presents the progressive gear construction reflected in the form of a computer model.

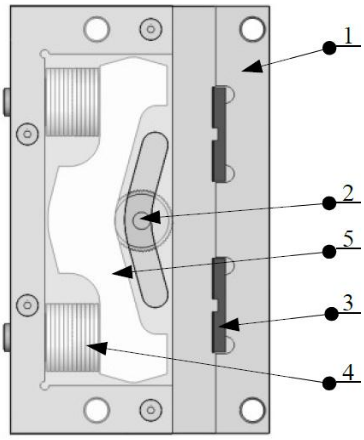

Fig. 1. Diagram of CHP2000 type progressive gears: 1 – a body, 2 – a braking roller, 3 – a braking plate, 4 – Belleville springs, 5 – a cam [5]

CHP 200 type gear consists of the body 1, where the cam 5 was located along which the braking roller 2 with knurled surface moves. Between the cam and the body the packets of Belleville springs 4 with variable configuration depending on a nominal loading capacity of the lift device were installed. During the operation the gear moves along the lift slide (pos. 6 in Fig. 2), which is placed in the gear body between the braking roller and the resistance plates 3 located in the opposite side of the Belleville springs packets.

The lift braking system together with the location of respective subassys coming into its construction are presented in Fig. 2.

The lift gear is located in the cabin frame 5 under the lift cabin. The lever 4 is mounted to the gear, its ends are connected with the speed limiter line 2. At the top part of the lifting shaft there is the speed limiter located which supervises the lift operation and at the bottom part of it there is a tensioning weight which is responsible for the proper speed limiter line stretching.

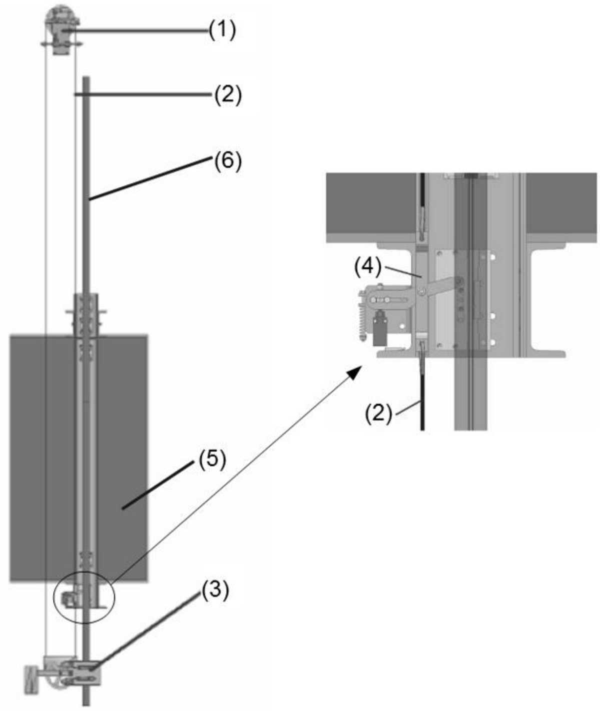

Fig. 2. The location of the braking system subassys of the friction gear, 1 – the speed limiter, 2 – the speed limiter line, 3 – a tensioning weight, 4 – a gear with a lever assy, 5 – the cabin with a frame, 6 - a guide [6]

The speed limiter initiates the braking process when the nominal speed of the lift cabin is increased by 0.3 m/s. Once the speed is exceeded the speed limiter is blocked and at the same time the line by properly selected friction coefficient is also blocked. During the lift cabin movement when the line is motionless the lever 4 is displaced in the opposite direction to the direction of the moving cabin and lifts the gear braking roller. The roller is pressed to the slide due to which the elastic deformation is created in the direction of the resistance plate which is placed on the other side of the Belleville springs packet causing the energy loss of the speeding up mass. The Belleville springs packet is responsible for the fact that changeable force is created. The force presses the roller to the guide and it depends on the mass which is carried in the cabin when the braking process is initiated.

3. MODEL OF THE GEAR BRAKING

The variable parameters, which influence the gear configuration, are as follows:

- The nominal speed v [m/s],
- Loading resulting from the lift construction F [N].

The construction of CHP 200 type gears was designed and initially tested for the nominal loading with the set-up from 8000 to 20000 N. On the basis of the above presented variables, in order to ensure the proper operation, the gears susceptible element is selected in such a way that skidding appearing during the braking is as gentle as possible. That is why, the nominal loading is a sum of a couple of mass parameters (changeable and constant) mainly influencing the selection of the susceptible element which causes the braking process. The mass parameters variability constitutes the Ist criterion to select the susceptible element of the gear to ensure proper reliability while the braking process takes place.

Thus, F nominal loading of the gears is defined by a mathematical relationship (1) [0]:

$$F = \sum P, K, D, Q \tag{1}$$

where: P – the cabin weight (a constant parameter) [N],
K – the cabin frame weight (a constant parameter) [N],
D – the cabin doors weight (a constant parameter) [N],
Q – nominal loading capacity (a variable parameter) [N].

The IInd criterion for the suitable configuration of the susceptible element selection is the right level of delay at the moment of braking. Bearing in mind the variability of Q loading which is placed in the lift cabin, the value of the force created during the braking process by the susceptible element must be within a tolerance of the system loading: with the loading capacity and without the loading capacity. During braking, the load which is inside the lift cabin as per the literature [8] should be subject to overloading within a range from 0.2, to 1 g, where “g” stands for the acceleration of gravity. That is why, the construction of a susceptible element of the gear should be matched in a such way that it is able to ensure average value of delay at the level of 0.6g during the braking process. With respect to the above, the braking force is described with a mathematical relationship (2) [0].

$$F = \frac{\text{Braking force}}{16} \tag{2}$$

While analyzing the empirical relationship (2), it should be noticed that the value of “braking force” which is supposed to be created by the gears during the emergency braking should be 16 times bigger than the value which is required to brake the cabin in movement.

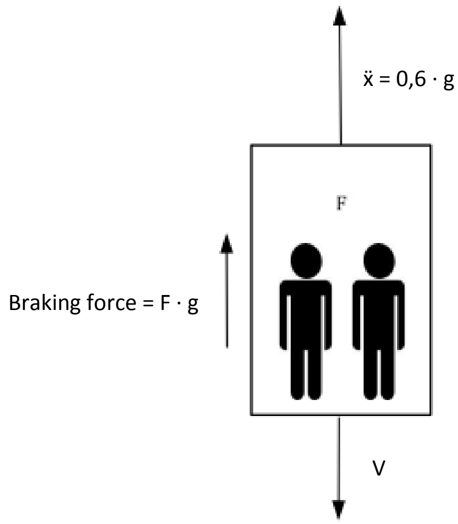

Fig. 3. The relationship between the speed, delay vectors and the braking force [3]

During the braking process, the value of braking force which is generated by the gear must defeat the weight of the whole system which loads the gears together with the loading capacity multiplied by the acceleration of gravity. The constant value, included in the empirical relationship (2) is the sum of accelerations of gravity value and the average value of braking delay 0.6 g which should be taken at the time of stopping the moving cabin system together with a changeable loading. The coefficient described in the relationship (2) is suitable for the value of gravity acceleration 10 m/s^2. Graphic relationship was presented in Fig. 3. It is the relationship between the v speed vectors, $\ddot{x}$ delay vectors and braking force.

However, bearing in mind complexity of the lift structure and changeability of the carried load weight as well as due to the variability of the system resulting from the lift operating conditions, in practice the I^{st} criterion is accepted to select susceptible elements in the gear.

4. METHODOLOGY OF THE INSTALLATION VALIDATION

CHP 2000 progressive gears construction was fully designed in SOLIDWORKS computer system and then it was pre-tested in the testing bench located in Lublin Factory of Passenger Lifts LIFT SERVICE S.A. The conducted tests aimed at determining whether a developed model of Belleville springs packet complies with the I^{st} criterion of the susceptible element selection or not. The performed tests gave the positive results. With respect to the above, as the next step the preparation of an effective system supporting the evaluation of the gear installation correctness should take place. For that purpose within the cooperation with Department of Mechanics at Lublin University of Technology the project of the workstation was developed. Due to that project it will be possible to perform the validation process of the gears installation in the production conditions. The validation system task would confirm whether the manufactured gears comply with specific parameters determined in the purchase order or not.

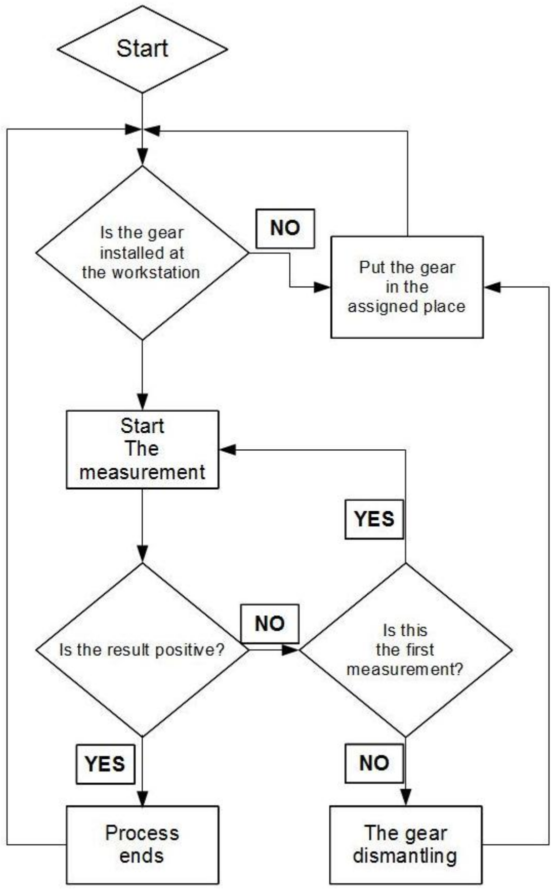

Fig. 4. The algorithm to control the validation workstation for the gears installation [9]

During the preparation of assumptions for the project the main attention was paid to the effective check of Belleville springs as the main susceptible element at the stage of the installation validation process. In order to ensure the correctness in the steps sequence during the validation, a block diagram was prepared. The block diagram is presented in Fig. 4. and it illustrates the methodology "step by step" of proceedings when the validation activities are conducted at the workstation.

In order to illustrate the validation of the gear installation at the production phase, Fig. 5 presents the project of the workstation to perform validation.

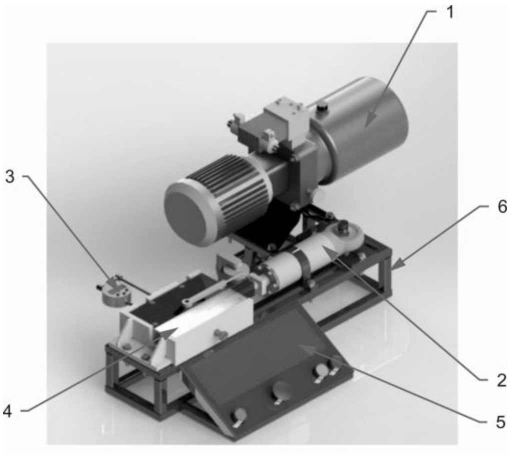

Fig. 5. The workstation to perform CH 2000 progressive gears installation validation [9]

The workstation designed in the computer consists of an engine with a pump 1, the engine drives a servomotor 2, a clockwork sensor 3, the validated gear 4, control desk 5 and the carrying frame 6. In order to perform proper validation of the gear installation, two basic indicators will be used: the pressure value read out from the manometer placed on the feeder and the value of the clockwork sensor deflection along which the Belleville springs responsible for the correct braking force will be located. Data received due to validation will be compared with the values of the gear carrying capacity set up at the beginning of the installation process [9].

5. CONCLUSIONS

In production processes of the elements responsible for safety, it is important to use diagnostic systems or systems validating the installation processes especially when the speed of production constantly increases. Direct advantages resulting from implementation of such a system in the company are the following:

- validation of the gears installation in the production without the need to check it on the object;
- the measurement of the carrying capacity directly after the installation;
- the execution of approximately 150 measurements without a need to retool the validation bench;
- the reduction of costs connected with missing parts;
- possibility to react on non-conformities immediately.

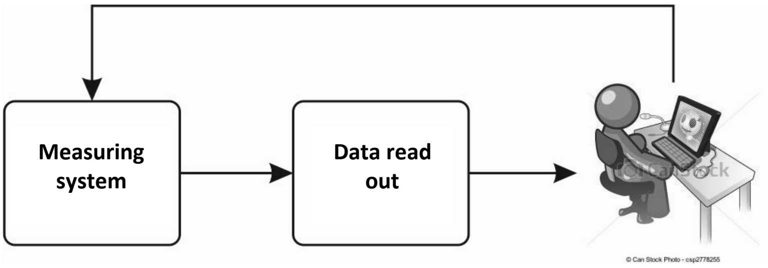

Fig. 6. A proposal of a decision making algorithm for the gears installation validation [source: own study]

The proposed system of the installation validation can be treated as the system of continuous supervision over the installed subassemblies (Fig. 6) as well as it can be correlated in its scope of work with the computer control system. Development of the field regarding decision making systems, validation and expert systems presently constitutes an important scientific subject. The product configuration changeability due to variability of the market demand constitutes a problem connected with the obstacles in the production cycle and leads to the process cost increase. With respect to the above, the implementation of such elements to the production processes allows us to reduce significant amounts of money connected with stoppages, defective production or storage of redundant subassemblies. The research study presents the project of a system which will provide a support not only to a decision but also thanks to the applicable system it will be possible to increase the production. When several pieces a day are manufactured the installation validation process is in the hands of the operator who has to decide on the classification of the item – "good/bad". Thanks to the implementation of the validation system there is a possibility to avoid not only a defective installation of susceptible elements but also to eliminate the remaining defects such as material defects. Such defects in a consequence of the installation validation can e.g. crack or deform what is unacceptable from safety point of view.

The presented system can be extended with strain gauge sensors which measure the gear stresses values caused by the braking force. Bearing in mind the above and the poor professional literature regarding the pertinent subject it seems purposeful to implement this validation system to production structures as well as to develop this field of interest.

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