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Identification of dynamic forces in the chain during the steady operation of a rescue scraper conveyor

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Abstract:

The article presents a study of the dynamic forces occurring in the chain of a rescue scraper conveyor during its steady operation. It describes the characteristics of the test stand in the form of a scraper conveyor for investigating dynamic forces in the chain, moreover, the results of these tests are presented. Based on the values obtained during the dynamic tests, the characteristic parameters of the above mentioned measurements were determined.

Keywords: plain link chain, scraper conveyor, tests of dynamic forces

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1. Introduction

The collaboration of the chain links with the drum, the joint interaction between the individual links in the articualted joint area, and the impact of aggressive environmental factors, account for the complexity of the wear processes of link chains. The most important factors that increase the degradation of chains and entire scraper conveyor assemblies are the following [1-7]:

– the occurrence of stone and coal dust in the chain link collaboration zone (articualted joints) [7-8],

– corrosive effects of mine water coming from sprinkler units and flowing out of goafs [9-16],

– dynamic loads from, among others, conveyor drive start-ups, uneven loading, frequent overloading and blocking [17].

The interaction between the aforementioned factors usually leads to the occurrence of synergy effect [18]. In order to determine the effect of synergy, it is necessary to determine the impact of a single degradation factor and the aggregate effect of their combined impact.

One of the above-mentioned factors that can act synergistically on the wear process of link chains includes variable dynamic forces. The impact is complex and often stochastic in nature, resulting from the uneven loading of the conveyor itself, the frictional nature of the movement of the conveyor belt and scraper elements in the trough, as well as other factors that are difficult to identify. Therefore, in order to represent the synergism of the aforementioned factors in the best way, an identification of the dynamic forces occurring in the chain tendon during steady-state operation of the rescue conveyor was carried out. For this purpose, a dedicated test stand was developed and built at the KOMAG Institute.

This article is part of a broader study related to the synergistic effects of environmental factors on chain link wear depending on the exploitation factors juxtaposed. In the work presented here, the determination of forces acting on the tendon system of a rescue scraper conveyor during its steady-state operation, for the above-mentioned research work, was carried out using a dedicated test stand (description in [19]).

2. Materials and Methods

2.1. Test stand

The test stand (Fig. 1-6) was built based on the rescue scraper conveyor possessed by the KOMAG Institute, equipped with the 14x50 chain strand. The research scraper conveyor under testing was composed of 10 trough sections and equipped with the main (active) drive and the return drive. The conveyor propulsion wheel was powered by a hydraulic motor, supplied by a hydraulic power pack and controlled from a separate station. The load-inducing element was a friction brake bolted to the scraper. In addition, the chain nominal load was varied by the chain pre-tension, adjusted through the turnbuckle installed in the chain strand.

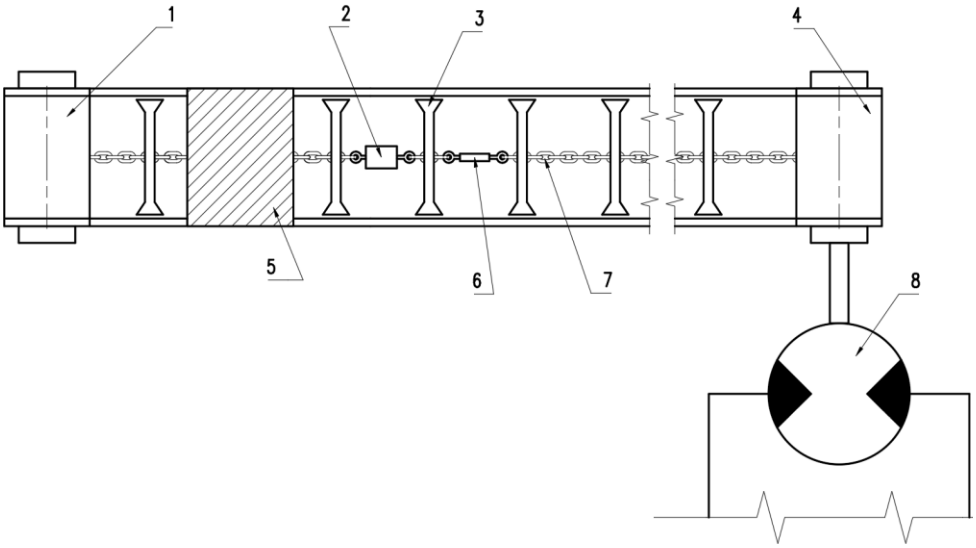

Fig. 1. Diagram of the test stand for dynamic forces in the rescue scraper conveyor (1- return wheel, 2- force sensor, 3- scrapers, 4-drive wheel, 5- friction brake, 6- turnbuckle, 7- chain, 8- hydraulic motor)

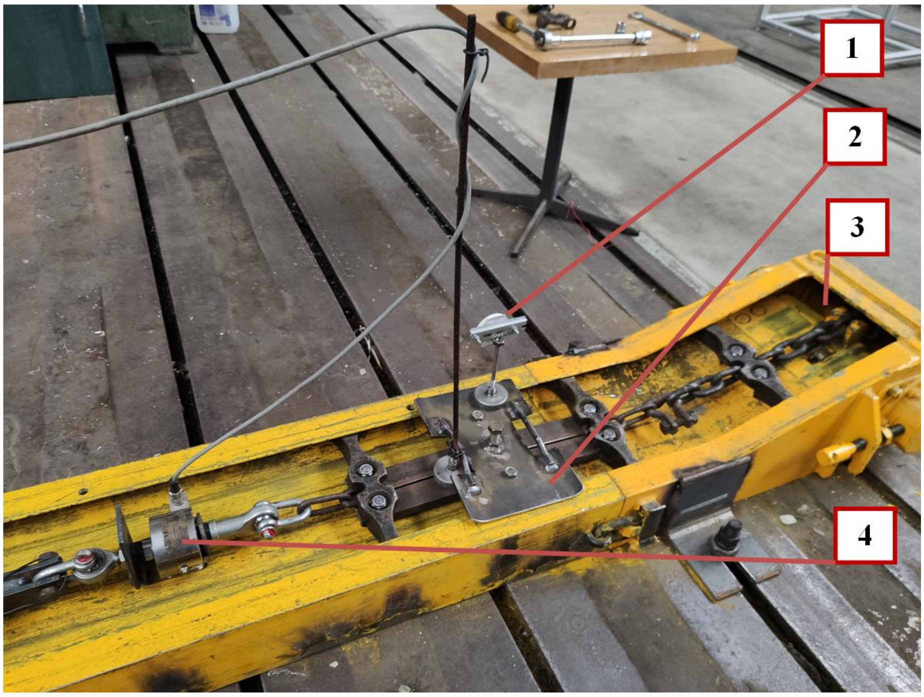

Fig. 2. Dynamic forces test stand – view from the return drive side (1- reflector, 2- friction brake, 3- return wheel, 4- force sensor)

2.2. Testing method

Tests of dynamic forces, occurring in the link chain, were conducted on a straight section of the conveyor. A U2A-2T force sensor manufactured by Hottinger Messtechnik Baldwin was used as the force measuring element. The sensor parameters are shown in the following Table 1.

Table 1. Technical parameters of the force sensor U2A-2T Hottinger Messtechnik Baldwin [20]

Parameter/physical quantity	Unit	Value
Nominal load	kg	2000
Construction material	-	Stainless steel
Accuracy class	-	0.2%
Sampling frequency (set)	Hz	50
Type	-	can-type weight transducer
Number of strands	-	6
Bridge constant	mV/V	2

Fig. 3. Stand for testing dynamic forces – view from the drive wheel side, markings: 1- hydraulic motor, 2- drive wheel

Fig. 4. Hydraulic control unit

Fig. 5. Measurement sensors, markings: 1- force sensor, 2- turnbuckle

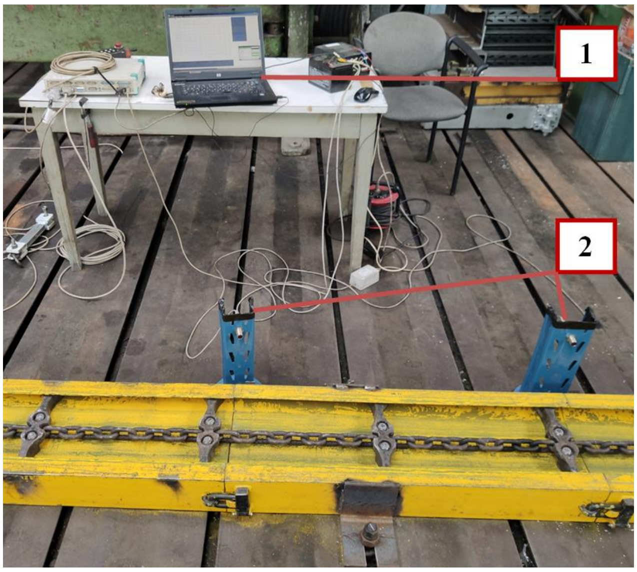

Fig. 6. Instrumentation for speed measurement and data processing, markings: 1- data processing and recording unit, 2- speed measurement sensors

The force sensor was mounted in the line of the link chain. In order to prevent it from being damaged, it was installed on a slide developed and manufactured at KOMAG, the design of which allowed the sensor to move smoothly along the conveyor without causing additional dynamic impacts when passing at the joints of the troughs. In addition, the test stand was equipped with a travel speed measurement system to allow testing at a constant conveyor speed. For this purpose, two optical sensors were used, installed along the route, at known spacing, calculating the speed of travel based on the time difference in the reading of the signal from the reflector mounted on the friction brake moving with the chain. The tests were carried out at a constant conveyor speed of ~1.3 m/s. The base (constant) load was generated by a friction brake installed on the route, and the load differentiation was carried out by the degree of chain tension set by the turnbuckle (read from the data provided by the force sensor). The tests were performed in 8 series - from an unstrained chain (initial load - 0 N) to the initial load of about 3237 N. Above this value, the operation of the conveyor was non-stationary due to the stick-slip effect occurring when the friction brake was moved. The parameters of the test series are shown in Table 2.

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Table 2. Parameters of the test series

Series number	The pre-tension of the tested chain S
1	0 N
2	490.5 N
3	686.7 N
4	1275.3 N
5	1863.9 N
6	2746.8 N
7	2943 N
8	3237.3 N

Each of the test series consisted of 10 principle runs and 10 return runs of the measuring element. By principle run the movement of the chain with the sensor in the direction of the drive wheel, and the return run - in the opposite direction are meant. A total of 160 runs were made, during which the value of the tensile force was recorded, as well as the control value of the supply pressure to the hydraulic motor of the drive unit. The series were started with a basic run in the drive direction, which were characterized by the presence of higher forces than for the sensor return movement (Fig. 7).

3. Results and discussion

The obtained results of measurements of dynamic forces in the chain and supply pressure are shown in Figures 8÷15 for All the test series (1÷8).

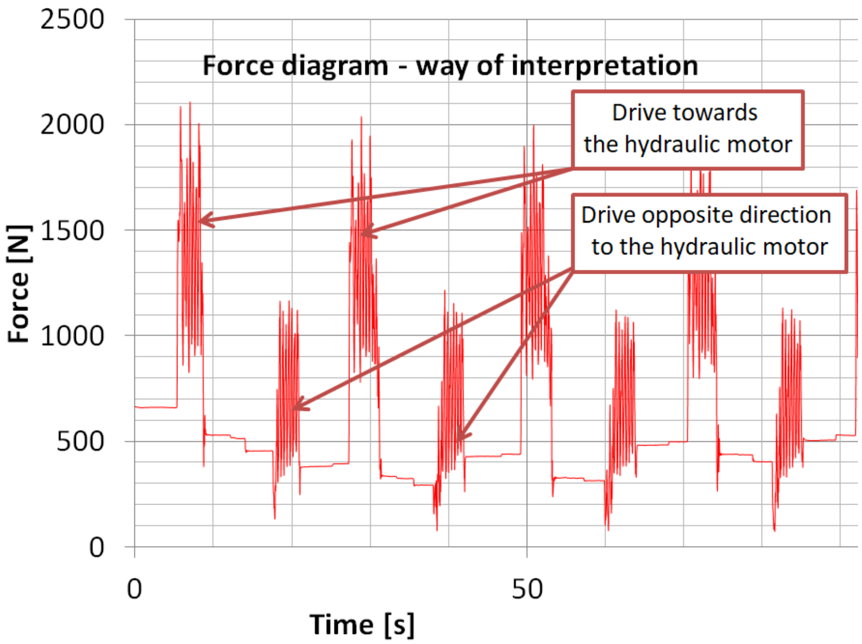

Fig. 7. Variation of the results of dynamic force measurements for basic and return movement.

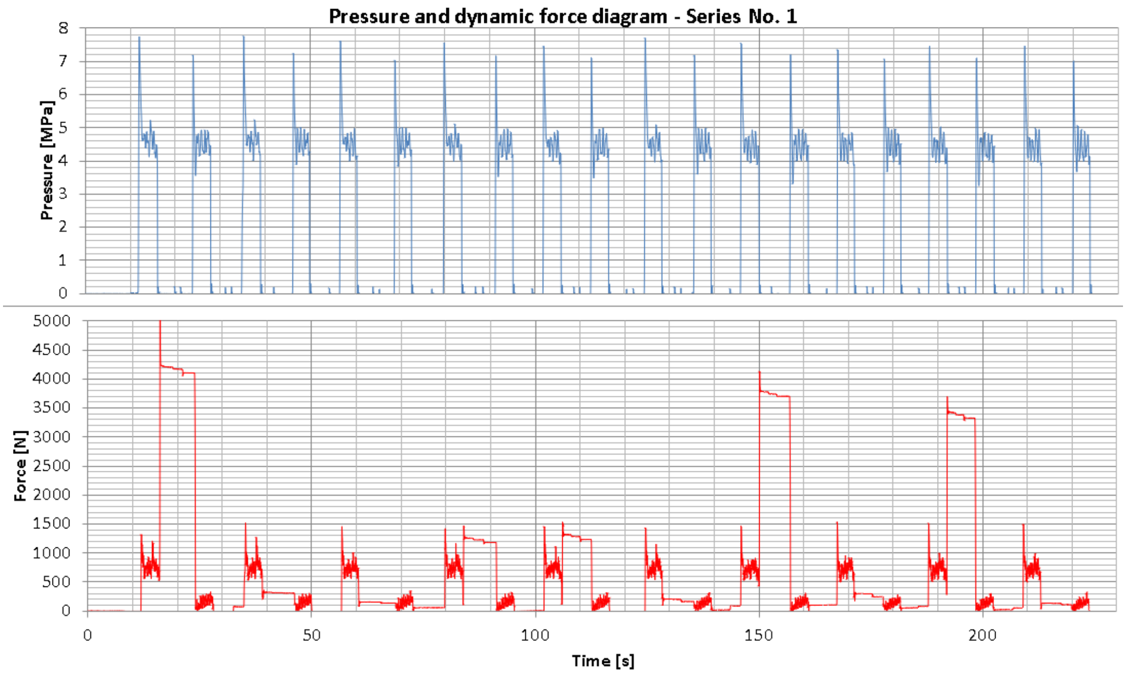

Fig. 8. Graphs of supply pressure (upper figure) and dynamic forces in the chain (lower figure) obtained for pretension S=0 N (Series 1)

Based on Figures 8÷15, it is possible to determine the basic parameters of the dynamic force in the chain strand during the travel of the rescue conveyor depending on the chain pre-tension. In addition to the differences in the values of the extreme dynamic forces depending on the initial load, significant differences in the forces depending on the direction of movement are also noticeable. Each time, higher force values are observed in the case of the movement direction corresponding to the tensioning of the part of the chain located in the upper compartment of the conveyor trough (the basic direction of the conducted tests). This phenomenon is directly related to the design of the conveyor itself and the orientation of the drive and return wheels in relation to the travel direction.

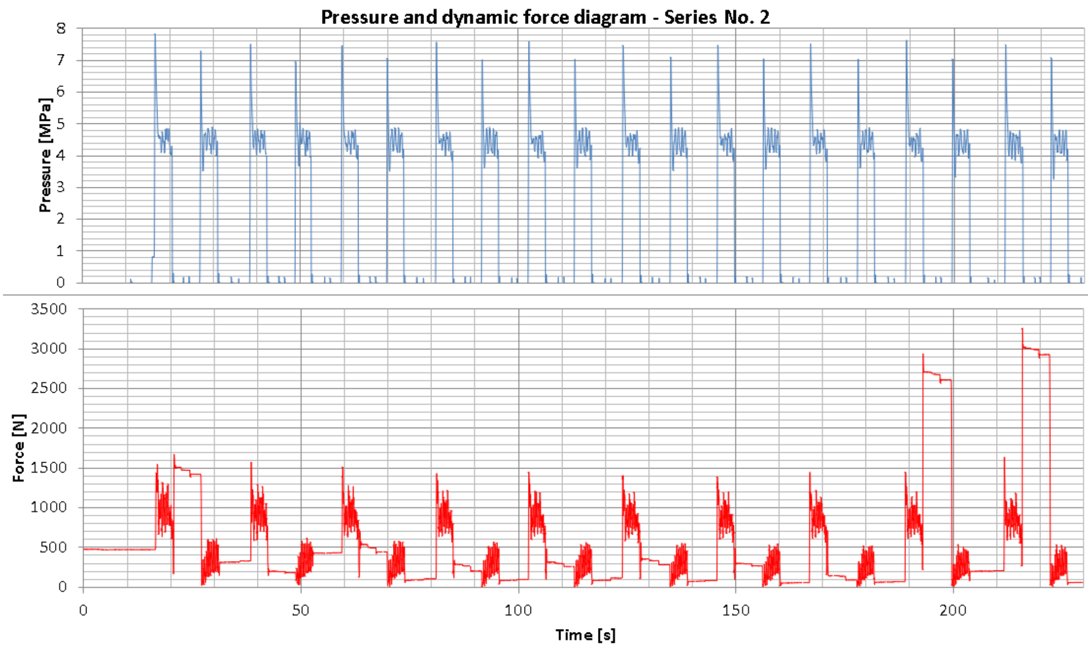

Fig. 9. Graphs of supply pressure (top figure) and dynamic forces in the chain (bottom figure) obtained for pretension S=490.5 N (Series 2)

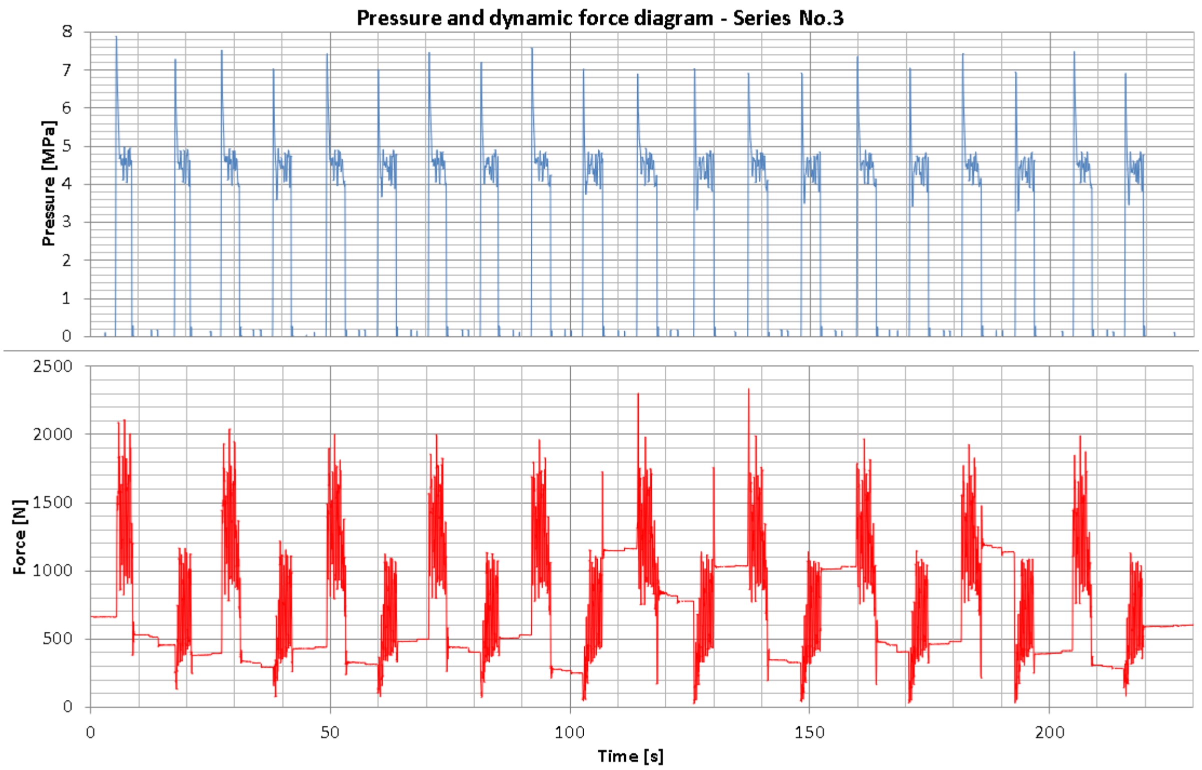

Fig. 10. Graphs of supply pressure (top figure) and dynamic forces in the chain (bottom figure) obtained for pretension S=686.7 N (Series 3)

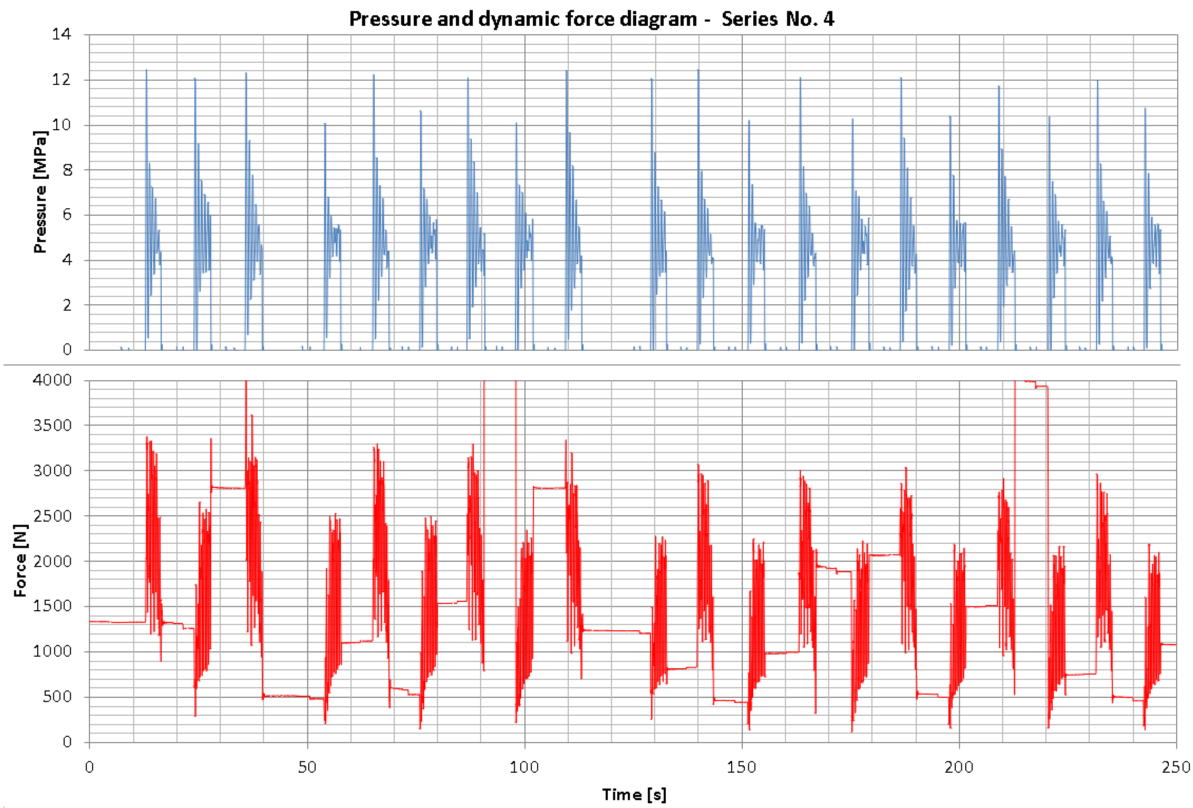

Fig. 11. Graphs of supply pressure (top figure) and dynamic forces in the chain (bottom figure) obtained for pretension S=1275.3 N (Series 4)

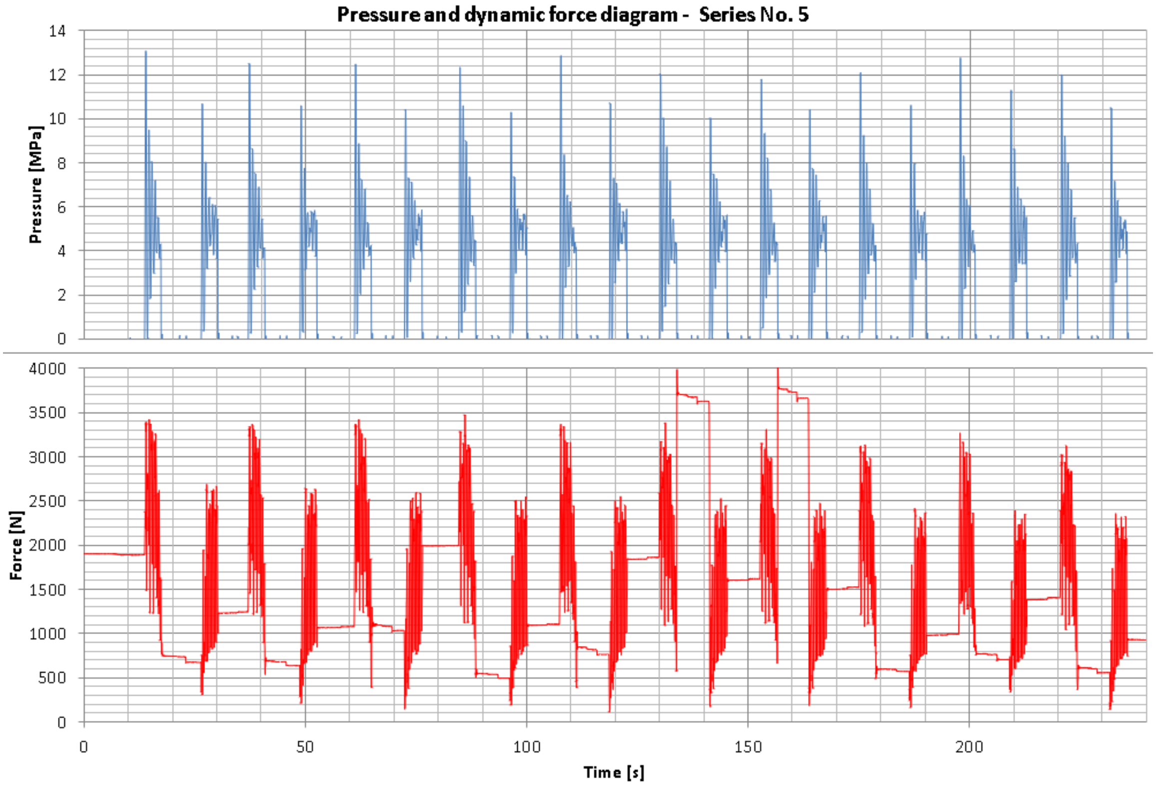

Fig. 12. Graphs of supply pressure (top figure) and dynamic forces in the chain (bottom figure) obtained for pretension S=1863.9 N (Series 5)

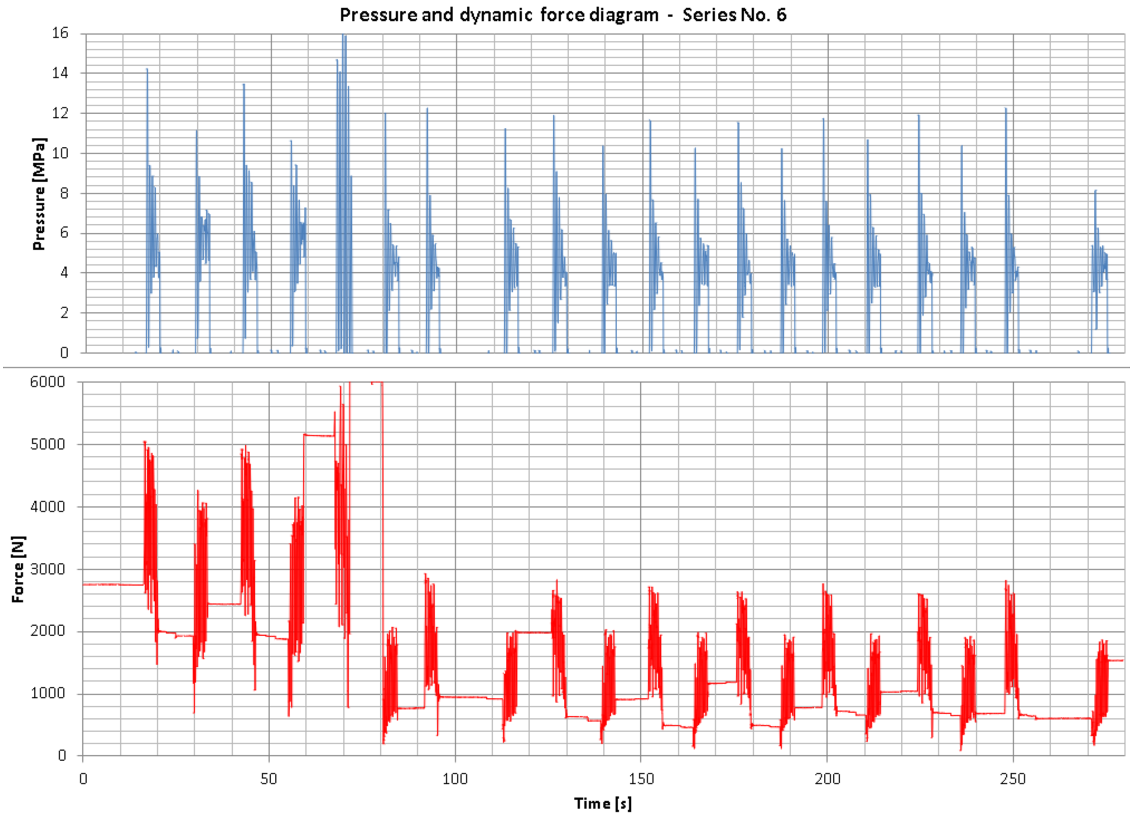

Fig. 13. Graphs of supply pressure (top figure) and dynamic forces in the chain (bottom figure) obtained for pretension S=2746.8 N (Series 6)

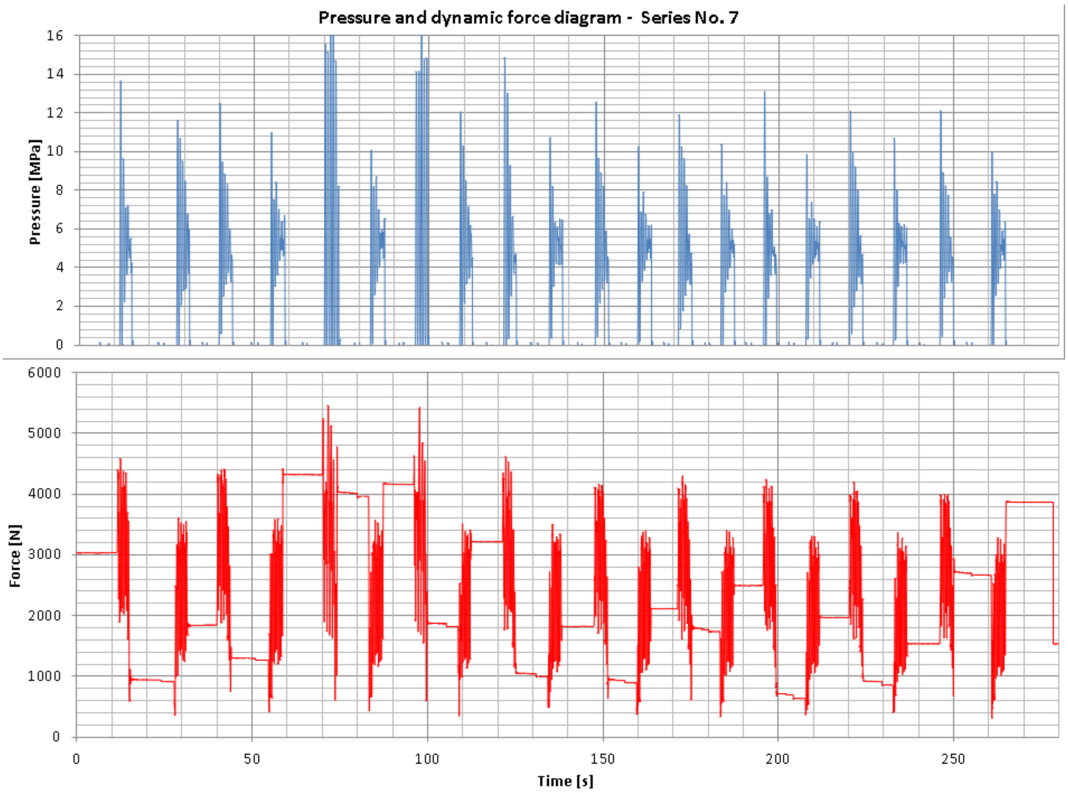

Fig. 14. Graphs of supply pressure (top figure) and dynamic forces in the chain (bottom figure) obtained for pretension S=2943 N (Series 7)

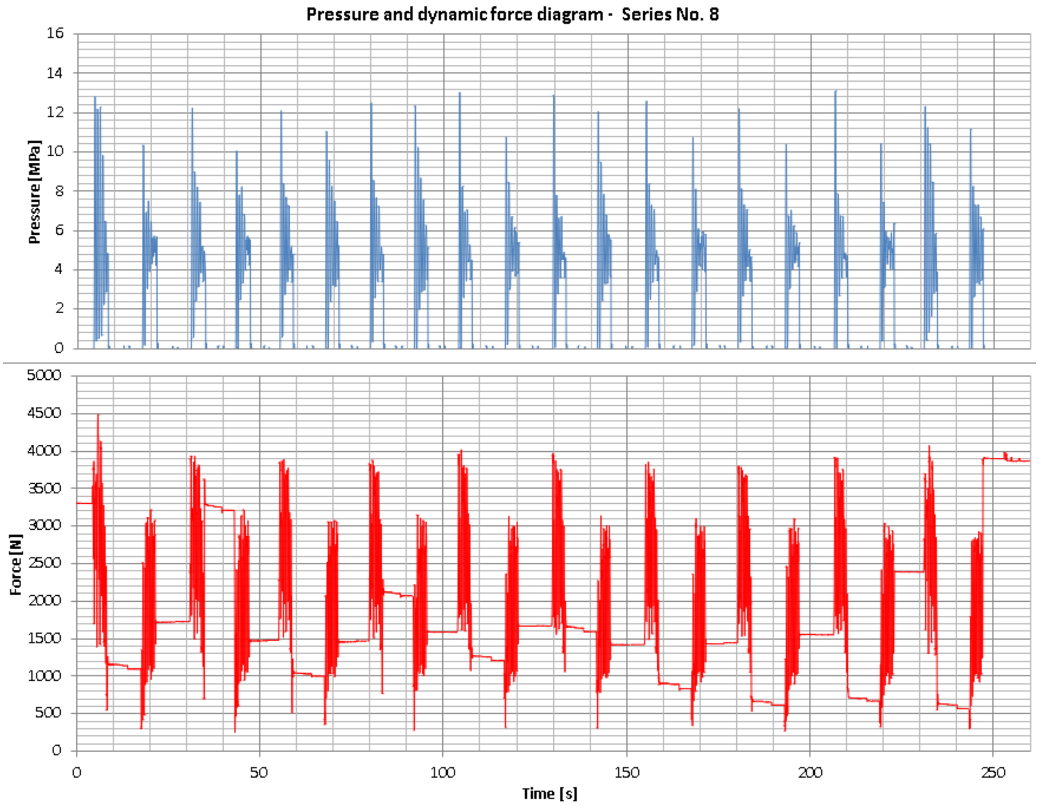

Fig. 15. Graphs of supply pressure (top figure) and dynamic forces in the chain (bottom figure) obtained for pretension S=3237.3 N (Series 8)

As it has already been mentioned before, the primary objective of the tests is an identification of dynamic forces in the chain of a rescue scraper conveyor for the purpose of mapping dynamic forces on a test stand for chain link wear synergism. The basic values characterizing the dynamic forces (Fig. 16) are the maximum (Max_F) and minimum (Min_F) estimates of the dynamic forces.

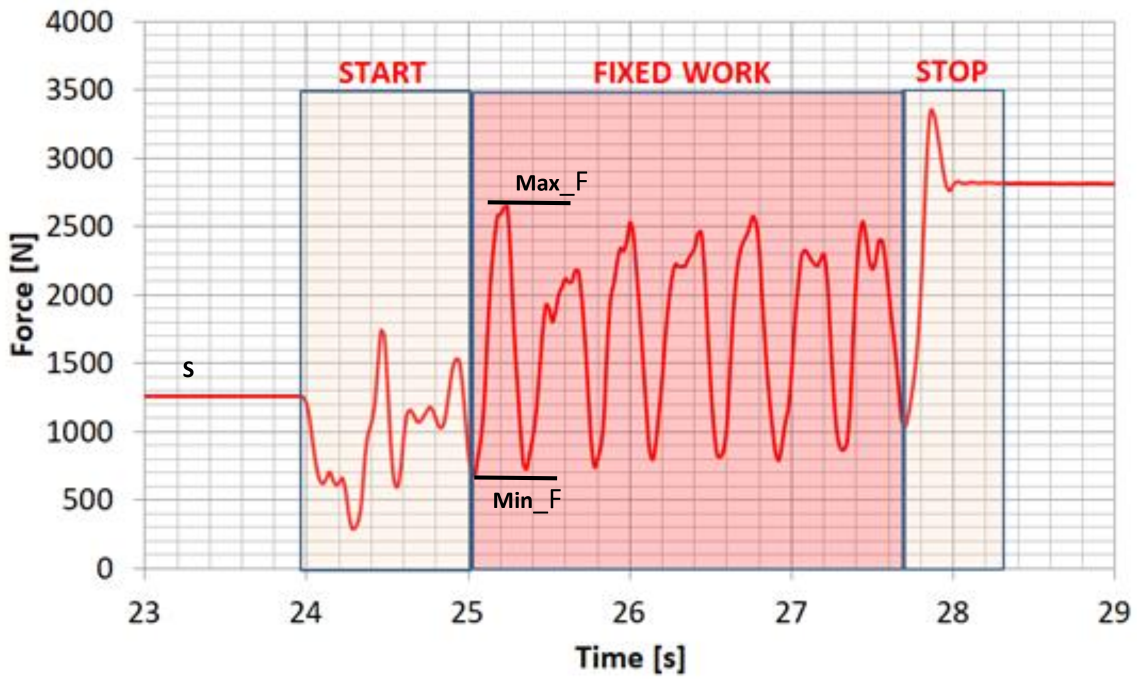

Fig. 16. An exemplary course of dynamic forces for one travel of the measuring head at the basic direction

Based on them, the amplitude A of changes in dynamic forces can be determined according to the relationship (1):

$$A = \frac{Max\_F - Min\_F}{2} \tag{1}$$

It is obvious that the actual forces loading the scraper conveyor will be different from the forces loading the test stand due to the inability of the test stand construction to carry big loads. As an adequate parameter, representing the actual variation of instantaneous forces acting in the chain, the ratio of the amplitude to the initial force A/S and the dynamic surplus defined by the following relation are accepted (2):

$$DS = \frac{Max\_F}{S} \tag{2}$$

The obtained values of dynamic forces and coefficients characterizing them are summarized in Table 3. In addition to the amplitude of the force, the frequency of dynamic forcing will be important for the proper presentation of the actual state, however, this issue will be the basis of further research work conducted by the authors.

Table 3. Results of measurements of forces and dynamic parameters

Base motion						
Series number	**S [N]**	**Max_F [N]**	**Min_F [N]**	**A [N]**	**A/S**	**DS**
1	0.00	1400	500	450	-	-
2	490.5	1500	600	450	0.92	3.06
3	686.7	2000	800	600	0.87	2.91
4	1275.3	3400	1000	1200	0.94	2.67
5	1863.9	3500	1200	1150	0.62	1.88
6	2746.8	5000	1000	2000	0.73	1.82
7	2943.00	5000	1000	2000	0.68	1.70
8	3237.3	4500	1500	1500	0.46	1.39
Return motion						
Series number	**S [N]**	**Max_F [N]**	**Min_F [N]**	**A [N]**	**A/S**	**DS**
1	0.00	300	0	150	-	-
2	490.5	600	50	275	0.56	1.22
3	686.7	1100	300	400	0.58	1.60
4	1275.3	2400	500	950	0.74	1.88
5	1863.9	2600	400	1100	0.59	1.39
6	2746.8	4000	400	1800	0.66	1.46
7	2943.00	3600	400	1600	0.54	1.22
8	3237.3	3400	600	1400	0.43	1.05

As the chain pretension increases, there is a noticeable increase in the minimum and maximum estimates for both the basic and return movements. For the basic movement, the minimum estimate ranges from ~500 to 1500, while for return movement it ranges from ~0 to 600. The maximum estimate is ~1400 to 5000 for the basic movement and ~300 to 4000 for the return movement.

The above results thus show an increase in the amplitude with increasing chain pretension. For the basic movement it varies from 450 to 2000 while for the return movement it varies from 150 to 1800. Thus, the ratio of amplitude to initial force in the A/S chain for the basic movement ranged from 0.46 to 0.94, while for the return movement it ranged from 0.43 to 0.74. Also the differences in the dynamic surplus, varying from 3.06 to 1.39 for the basic movement and from 1.88 to 1.05 for the return motion are noticeable.

4. Conclusions

The paper presents the test results of the dynamic forces acting in the chain during the steady operation of the rescue scraper conveyor. Based on them, the following conclusions were drawn:

- The values of the dynamic forces in the chain of the rescue scraper conveyor depend on the direction of the conveyor movement.
- The coefficients characterizing the dynamic forces, regardless of the direction of movement of the strand, decrease as the pretension of the chain increases.
- The ratio of amplitude to initial force in the A/S chain for the basic movement ranged from 0.46 to 0.94, while for the return movement it ranged from 0.43 to 0.74.

Based on the determined values of the relative coefficients, characterizing the dynamic forces in the chain of the rescue scraper conveyor, in particular the A/S parameter, a method of applying a variable load in the contact area if chain links will be developed.

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