Identification of the assembly line drive chain force load

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Abstract: The small digger assembly line is composed from the series of transport trolleys, which are slowly pulled around the mounting posts. All these trolleys are moved together by one towing chain. Increasing the number of trolleys was required during the assembly line upgrade, however a power unit including the towing chain should remain as originally. Therefore it was necessary to determine whether the chain will not be overloaded with a higher number of the trolleys. Methodology for the identification of the towing chain force load is described in this article.

Keywords: assembly line; towing chain; force load; measuring; strain gauge sensor.

1 Introduction

The small digger assembly line is composed from the series of transport trolleys, which are slowly pulled around the mounting posts. All these trolleys are moved together by one towing chain. The real assembly line and its functional principle are shown in the Fig. 1.

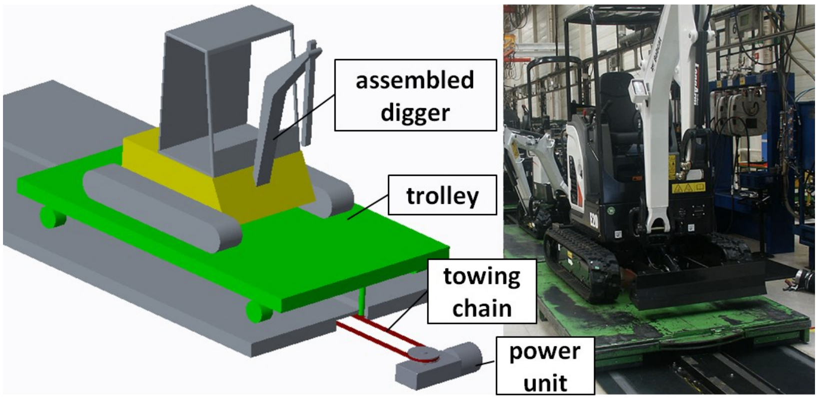

Fig. 1: The real assembly line (right) and its functional principle (left).

Increasing the number of trolleys (from 6 to 10) was required during the assembly line upgrade, however the power unit including the towing chain should remain as originally. Therefore it was necessary to determine whether the chain and the power unit will not be overloaded with a higher number of the trolleys.

The towing force can be theoretically calculated from the wheel load and the rolling resistance coefficient by the next simple equation (see [1]):

$$F_t = c_{rr} F_n \tag{1}$$

where F_t is the towing force, c_{rr} is the rolling resistance coefficient and F_n is the normal force (see Fig. 2)

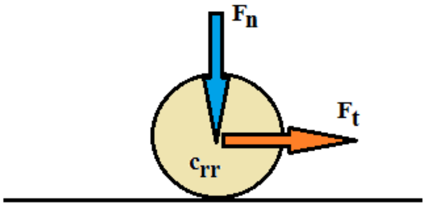

Fig. 2: The towing force theoretical calculation.

The rolling resistance coefficient depends on the floor and the wheel material and its values are published for the most used material pairs [2]. Obviously the bearing properties, the wheel shape and the dimension must be reflected for the wheels that are really used, however the towing force calculation is the same. The wheel producer publishes the rolling resistance coefficient (often called as a traction coefficient) for an every wheel and any floor type and it is used for the real towing force calculation.
So this approach was used for the assembly line towing force calculation. The trolleys have wheels with plastic surface and run on the steel track. Their producer specified the traction coefficient value 0.01828. The load distribution for the old and the new assembly line is shown in the Fig. 3 and the towing force theoretical calculation results are summarized for the both line variants in the Tab. 1.

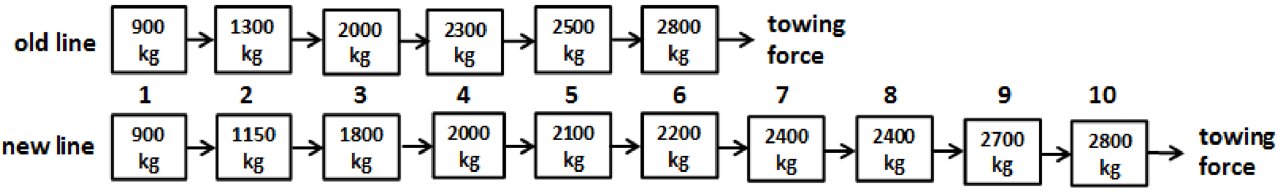

Fig. 3: The old and the new assembly line load distribution.

Tab. 1: The towing force theoretical calculation.

traction coefficient	0,01828	mounting post										total	
		1	2	3	4	5	6	7	8	9	10	vertical load [kN]	towing force [kN]
trolley weight [kg]		300	300	300	300	300	300	300	300	300	300		
digger weight [kg]	original line	900	1300	2000	2300	2500	2800	x	x	x	x	133,4	**2,4**
	new line	900	1150	1800	2000	2100	2200	2400	2400	2700	2800	230,0	**4,2**

The real towing force value can be different from its theoretical calculation because the traction coefficient value can be affected over the time by the wheels wear out, dirt, uneven floor, etc. Therefore the assembly line producer needed to verify whether the real force corresponds to its theoretical calculation and the power unit and the towing chain will not be overloaded after the line upgrade.

2 The real towing force measurement

Because the towing chain is located in a very narrow groove, the standard force sensor could not be used for the towing force measuring. Therefore the force was measured by the strain gauge sensors glued to one part of the towing chain. This part was first weakened for the sensitivity increasing and two identical strain gauge sensors HBM 1-LY41-6/350 [3] were glued to the inner chain surfaces (see Fig. 4). Each strain gauge was connected separately as a quarter-bridge, two signals were used for the force measuring. The ambient temperature change during a short term measurement was not expected, therefore the temperature non-compensated quarter-bridges could be used.

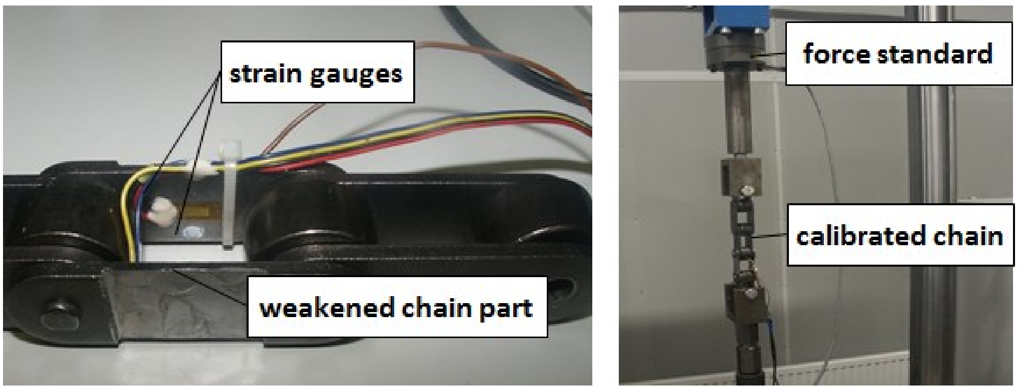

Fig. 4: The chain part with the strain gauges (left) and its calibration (right).

The strain gauge signals were calibrated to the force value using the laboratory calibration system and the total force was calculated as their average. Possible both chain sides uneven loading was eliminated with this. All this was done before the real force measurement at the Technical University of Liberec laboratory.

Finally, this part of the chain was included to the assembly line towing chain (see Fig. 5) and the real force was measured during the assembly line trolleys movement. Two measurements were planned initially (first before and second after the line upgrade) because the line producer wanted to compare these two operating statuses. Third measurement had to be added later because the towing chain tensioning mechanism failed after some assembly line operation time and the cause had to be detected.

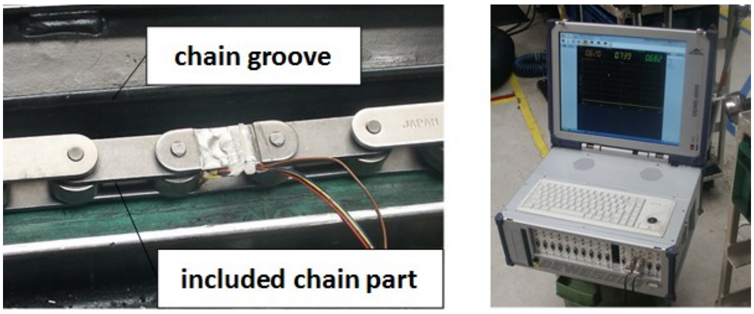

Fig. 5: The real towing force measurement.

3 Results

All the measurements were done in the same way. The assembly line movement was stopped, its towing chain was discontinued and the measuring chain segment was included. Then the line traction was launched and a displacement of approximately one meter was measured. All the trolleys were standard loaded by the assembled diggers but no production operation was done during the first two measurements.

The real towing force measured waveforms (see Fig. 6) slightly fluctuate due to the imperfect and dirty floor but their mean values in a steady state practically correspond with the calculated values (2,4kN for 6 and 4,2kN for 10 trolleys). Because the traction engine is controlled by the frequency converter, the line start is smooth, without the towing force peaks.

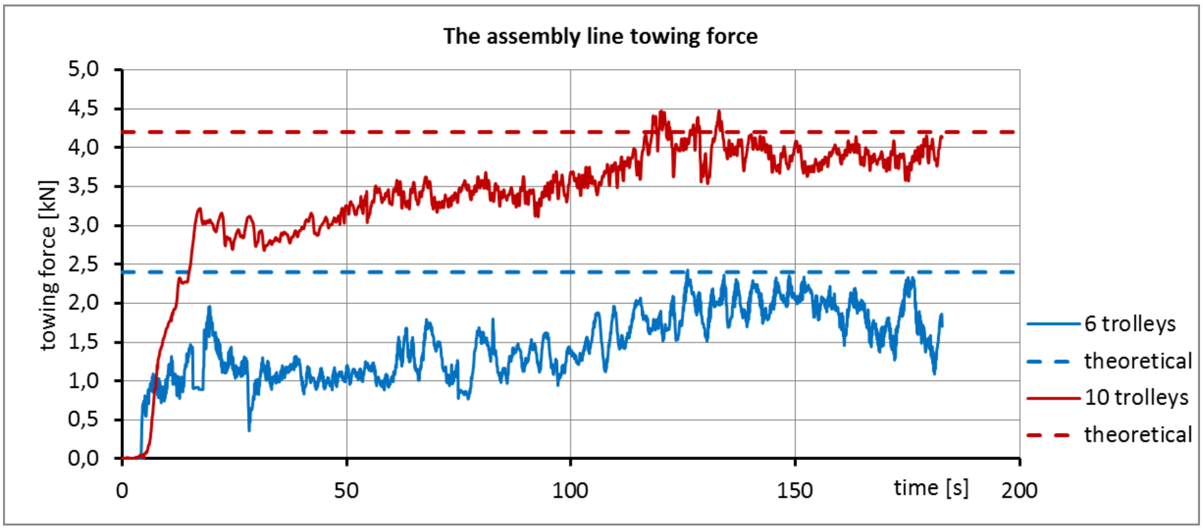

Fig. 6: The real towing force waveforms.

The first two measurement results were clear, the assembly line components are not overloaded by the trolley number increasing, the real towing force value corresponds to its theoretical calculation. The assembly line was put into operation on this conclusion basis. But the towing chain tensioning mechanism unexpectedly failed after some time and it was in a contradiction with the previous results. The entire production process was then analyzed and probable cause of the failure was determined. A new checking operation was added in the production line. All the digger functions began to be tested at the station no.9 before the digger final covering. Its hydraulics systems were activated and all the digger movements were tested. Obviously, the digger was still on the trolley, which was attached and moved by the towing chain, and all the assembly line traction system was loaded by the moving mass inertial forces. Verification measurement before the production line using was done without this checking operation, the trolleys were loaded only by the static mass. The assembly line producer did not foresee this situation because the diggers were previously tested outside the assembly line, after their final completion. Therefore a new measurement of the towing force was done during the normal line operation, including the digger function test. The result is shown in the Fig. 7.

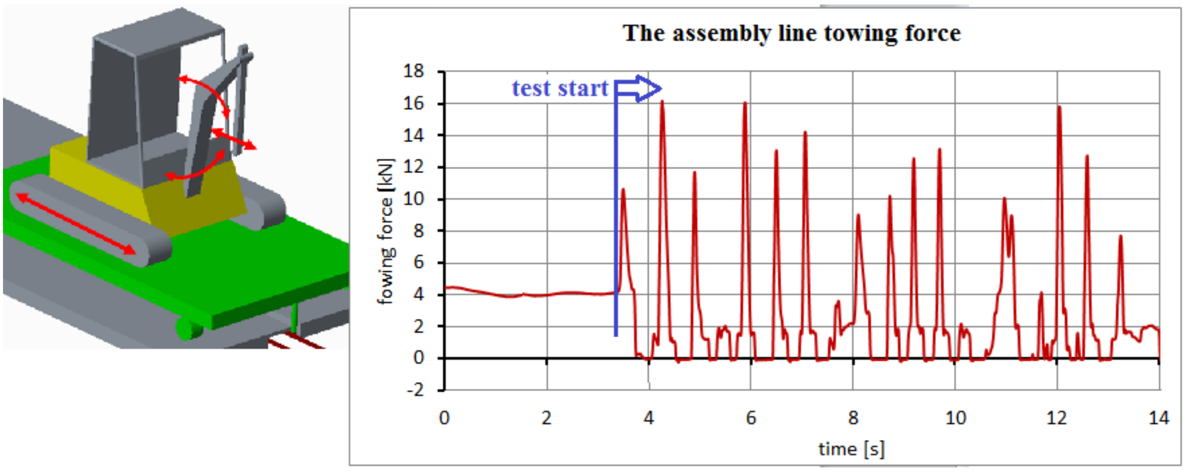

Fig. 7: The towing force waveform during the digger function test.

The measured waveform shows that the towing force before the function test corresponds with the assumption value 4.2kN but the very big peaks are caused by inertial forces during the digger test. Their maximal values increased up to 16kN. The inertial forces dynamical effect is four times greater than the static loading. The towing chain is not overloaded (its maximum allowed force is still much bigger than the force peaks) but its tensioning mechanism was not designed for this dynamical loading and it is approximately twice overloaded by the dynamical force peaks. Therefore the failure assumption was confirmed by this additional measurement.

4 Conclusion

All the measurements showed that the static tensile force corresponds to the theoretical values and the assembly line design was made correctly. The tensioning mechanism failure was caused by adding of a new checking operation which was not initially considered. There are two possible ways to solve this problem and neither of them is an easy one. The first option – return to the outside assembly line testing – decreases a productivity, the second way - with the “on trolley” digger testing – requires the assembly line modification (the tensioning mechanism redesign or the trolley disconnecting and braking during the digger test). The final decision depends on the assembly line producer and it is beyond a scope of this article. This paper is focused only on the towing force measuring methodology and the presentation of this measurement results.

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