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Research on Innovative Mode of Preventing Train Derailment Under Emergency Braking Condition of Super-Long Heavy-Load Train

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Abstract: After many years of operation practice and academic research, the author found that after the 1800 meter long heavy haul train had emergency braking, the dangerous "vehicle lifting and squeezing moment" was transferred from the head to the tail of the train one by one, which was called "wall collision effect" in the passenger service; Especially for combined trains, the phenomenon of vehicle lifting and squeezing is particularly obvious, Especially for combined trains, the phenomenon of vehicle lifting and squeezing is particularly obvious, and the derailment probability of locomotives in the middle increases greatly, which seriously threatens the operation safety of overlong heavy haul In this paper, the author boldly breaks through the traditional thinking and creatively puts forward a new idea that the braking torque of super long heavy haul train transforms the existing extrusion emergency braking parking from the front to the back should be generated the more safe " stretching state" parking from the rear stretching state" parking from the rear to the front, changing the transmission direction of the braking torque from "front to back" to "back to front", which greatly reduces the derailment coefficient of the super long heavy haul train under the emergency braking condition.

Keywords: Super Long Heavy Haul Train, Emergency Braking, Braking Torque

1. Introduction

In the face of the increasingly busy industry situation of railroad freight transport tasks, the operation of extra-long heavy-duty trains is an effective measure to significantly improve the capacity of railroad freight transport [1]. However, "extra-long", "heavy load" two major features, making the extra-long heavy train in the operation of emergency braking, the whole train adjacent vehicles appear between the multiple directions of the vehicle lifting moment; excessive vehicle lifting moment, there will be vehicle wheel pairs are lifted out of the rail situation, resulting in the serious consequences of train derailment.

When the emergency braking of over-length heavy-duty trains, the train brakes in the implementation of air line braking, the train tube air wave propagation time is long, resulting in the braking of the front of the train and the rear of the vehicle is not synchronized, [2] so that the over-length heavy-duty trains produce a strong longitudinal impact moment and the transverse lifting and squeezing moment between the hook and the hook, seriously threatening the transport safety of over-length heavy-duty trains, according to the Academy of Railway Sciences on the operational safety of over-length heavy-duty trains According to the control limits of the Railway Academy of Sciences, the derailment coefficient ≤0.90; wheel weight reduction rate ≤0.65; axle transverse force ≤97kN, so the emergency braking of long and heavy trains should control the corresponding data within the controllable range.

At present, there is no detailed research and demonstration on the safety technology of the ten thousand tons of heavy haul of the super-long railway train from the head exhaust braking or from the tail exhaust braking. The author is an innovative scholar in the field of the ten thousand tons of heavy haul of the Chinese railway. His paper fills a gap in the safety technology of the ten thousand tons of heavy haul of the super-long railway.

Extra-long heavy-duty trains in operation moment impact is more complex, in the traction condition in the tension state, the braking condition in the compression state, traction and braking conditions of the longitudinal moment, tension and compression state of the positive and negative moment, is the point of conflict between the vehicle and the vehicle.

To this end, the safest operating condition for long and heavy trains is "moment singulation", the fewer the force factors, the better to control the long and heavy trains under braking conditions, how to reduce the longitudinal impact moment is the focus of our research.

2. The Current Situation of Braking for Extra-Long Heavy-Duty Trains

At present, the extra-long heavy-duty trains of NNPC Baoshen Railway are divided into two categories: "unit 10,000-ton heavy-duty trains" and "combined 10,000-ton heavy-duty trains". The State Energy Baoshen Railway operates 132 10,000-ton heavy-duty trains in 2+2 (DC) combinations and 108 10,000-ton heavy-duty trains in 3+0 (AC) units. [7] Both forms of traction grouping mode use wireless synchronous manipulation technology, the wireless synchronous manipulation technology although effectively enhance the problem of braking system synchronization. However, due to the signal delay or poor signal caused by the strength of the wireless synchronous braking command signal, it still cannot guarantee the consistency of the braking signal in the first time, and fails to truly solve the synchronization of the braking and relief of the extra-long heavy-haul trains.

At present, the brakes of China's long and heavy-duty trains are all "air pipe braking and relief" technology, and the locomotive brakes at the head of the train control the "air filling" and "air exhaust" of the attached vehicles. [8] The braking and relief of the whole train is achieved by the locomotive brake at the head of the train, which leads to the longitudinal compression torque when braking and longitudinal tension torque when relieving the train. [9]

The locomotive is in tension when the train is in traction, and the train is in compression when the locomotive is in braking condition. [12] Especially in the emergency braking of the long and heavy train, due to the emergency braking of the train head locomotive and rapid exhaust, the head locomotive train tube pressure, instantly with the train tube pressure of the train tail vehicle, resulting in a huge pressure difference of 0 ~ 600Kpa; [4] the braking efficiency of the head locomotive vehicle and the braking efficiency of the tail vehicle also produced a huge impact. [10]

The train produces a huge "compression moment" from front to back is the production site of the "wall effect", and then overlap additional because between the two vehicles, the hook buffer and the lateral gap between the hook buffer, producing an intricate "lifting moment". [13] The "lifting and squeezing moment", these two moments superimposed together, greatly increased the risk of train derailment. [11] 3 + 0 unit of extra-long heavy-duty train emergency braking hook force analysis as shown in Figure 1, emergency braking time as shown in Table 1.

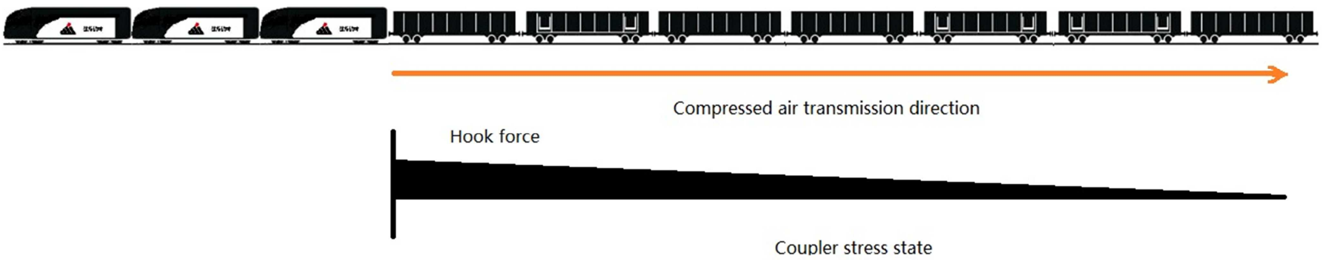

Figure 1. *Analysis of hook forces during emergency braking of 10,000-ton unit trains.*

Table 1. *Unit 3+0 emergency braking time test results for extra-long heavy-duty trains.*

Test Parameters		1 bit C80	116 bits C80
Braking	Brake cylinder pressure (kPa)	478	475
Process	Start gate exit time (s)	0.6	6.8

The analysis of the force on the hook during the emergency braking of the 2+2 combination extra-long heavy load train is shown in Figure 2, and the emergency braking time is shown in Table 2.

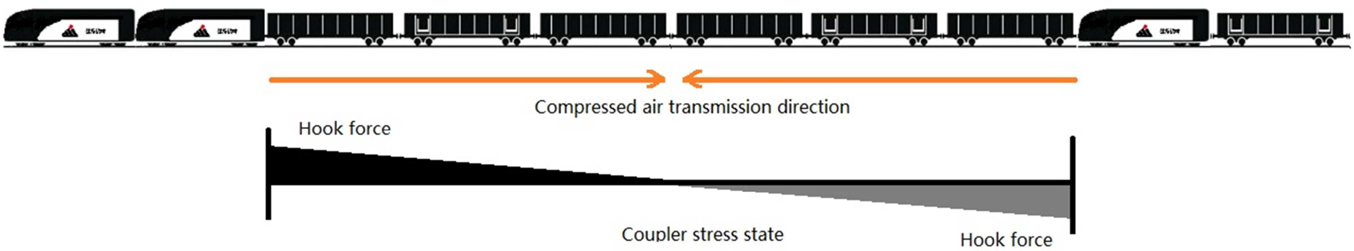

Figure 2. *Analysis of hook force during emergency braking of 10,000-ton combination train.*

***Table 2.** 2+2 combination of ultra-long heavy load train before the small train emergency braking time test results.*

Decompression volume	Exhaust air time	Train tube pressure and air filling time		Remarks
Emergency braking	5.5	580 kPa	254	

Through the analysis of the above data, no matter which wireless synchronous braking signal is used, the whole train in the implementation of emergency braking, the locomotive and the last car braking time will be different in more than 5s, [3] and after the emergency braking generated by the extra-long heavy load train, the whole train is not the same time to produce the braking effect, the braking effect along the train running in the opposite direction from the front to the back to pass one by one, which produces the "braking wave".

The existence of the braking wave makes the braking action occur from the first one at the front of the train to the back one by one, the braking rate of the front vehicle is large, the braking rate of the rear vehicle is small, and the difference of kinetic energy is formed between each vehicle, which leads to the relative motion of the 2+2 combination of super-long heavy-load train squeezing from both ends to the middle of the front small train, and the relative motion of the 3+0 unit super-long heavy-load train squeezing to the first locomotive, and converts the difference of kinetic energy into The hook buffer spring energy storage, which causes the compression of each hook buffer spring of the train, the compression is static compression, this compression has a certain action speed, so it is expressed as the longitudinal power of the train energy storage, so that the train runs smoothly.

During the emergency braking of the 2+2 combined long and heavy load train and 3+0 unit long and heavy load train, the longitudinal hook force of the train is instantly greater than 2250kN, which exceeds the safety control limit and will cause great damage to the locomotive traction buffer device of the long and heavy load train. At the same time, the 2+2 combination of long and heavy train "front pressure and rear top", "front pulling and rear tugging" and other kinds of moments are generated, especially after the emergency braking effect of the long and heavy train, multiple moments are superimposed, and the hook and the hook between the relatively dangerous The "lifting and squeezing moment" will increase, and the derailment factor will be relatively high. [15]

After the braking machine test data of the Railway Academy of Sciences, the safety recommendations of the extra-long heavy-duty trains are assessed by the following indicators: normal maximum hook force ≤ 1000kN; maximum hook force ≤ 1500kN during braking; longitudinal acceleration of the car ≤ 9.8m/s; hook deflection angle ≤ 6° from the control locomotive. [12] If the extra-long heavy-duty train in the case of emergency braking, the longitudinal moment of mutual lifting and squeezing superimposed on each other, the strength is large enough to exceed the safety limit, there will be broken hooks, derailment and other serious consequences. [14]

3. Heavy-Duty Train Brake Technology Innovation Upgrade

After several years of heavy-duty transport practice has proved that the central locomotive of the extra-long heavy-duty trains, in the case of emergency braking, the hidden danger of being lifted and squeezed increases, and the phenomenon of car dislocation failure also increases, and the hidden danger of derailment also increases, so in the actual locomotive operation management requirements clearly stipulate that "when encountering the safety of the train operation is endangered, only when the emergency brake measures, other cases to common brake stop".

In order to make up for this safety hazard, we use innovative thinking to boldly change the transmission of braking force of over-length heavy-duty trains from the traditional "forward to backward" transmission to "backward to forward" transmission; and change the dangerous "compressive torque The dangerous "compressive torque" is converted to "tensile torque", so that the long and heavy trains in operation can maintain a safe running state, which is the "tensile state".

4. Technical Transformation

4.1. Extra-Long Trains with a "Controlled Tail" from the Rear of the Train to Control the Exhaust Air

The currently used column tail device is ZTF2002-6 controlled digital column tail, the column tail device can realize the main control locomotive braking machine failure in the case of the column tail device common exhaust parking, but not the implementation of the emergency braking role of the column tail device. Therefore, to upgrade the emergency braking function of the programmable tail is the preferred solution to improve the safety coefficient of long and heavy trains in the emergency braking condition.

When the running train is in an emergency, the driver uses the controlled tail to apply the emergency brake, the specific operation process is as follows. [5, 6]

1) Connect the controlled train tail emergency brake function to the emergency brake button circuit on the driver's console.
2) When the driver applies emergency braking, press the "emergency brake" button to send an emergency brake command to the rear of the train, the rear of the train can be controlled by the rear of the host immediately produce emergency braking effect.
3) The main control locomotive driver implements emergency braking → the controllable column tail implements emergency braking from the rear of the train for emergency exhaust.

The technology focuses on placing the train emergency brake vent at the rear of the train, using a controlled train tail for emergency brake venting. The emergency braking wave speed of the train is converted from the existing "front to back" transmission to "back to front" transmission, thus prompting the train to stop in a stretched state.

Emergency braking logic control for extra-long heavy trains.

1) The main control locomotive implements emergency brake → the main control and re-linked locomotive disconnects the main circuit breaker in the case of non-zero position of speed control hand wheel → the controllable column tail or tail locomotive implements emergency brake.
2) train emergency braking wave speed, will be controlled from the rear of the train forward one by one, until it reaches the front locomotive, so that the train braking torque "from back to front" transfer.
3) train emergency braking torque "from back to front" transfer, will produce the train "steel whip effect", can ensure that the whole train in a stretching attitude stop, the whole train hooks are in the pull hook state; like a stretching steel whip, from back to front to produce a backward pull The force of the train will be pulled backwards.

The principle of emergency braking and the force on the hook of the train are shown in Figure 3.

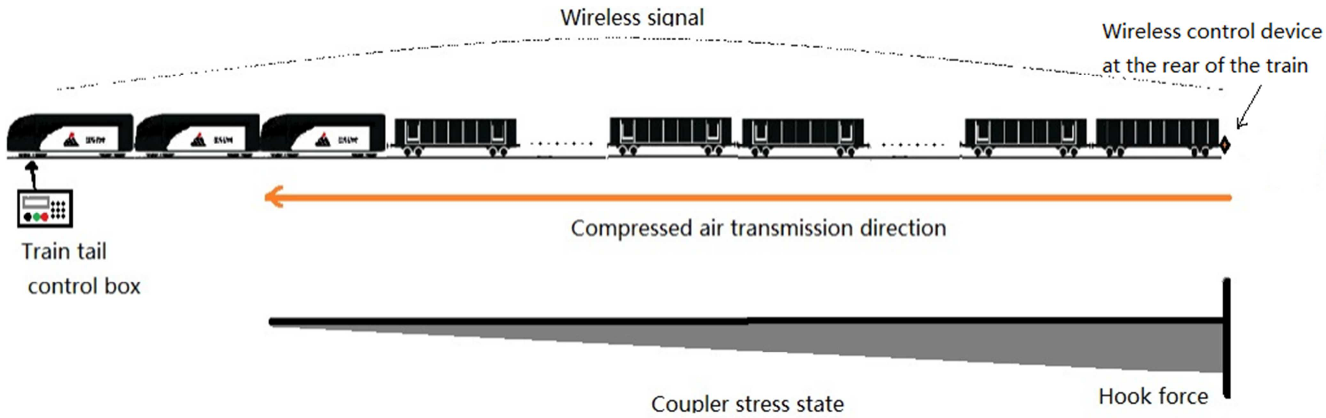

Figure 3. *The principle of emergency braking at the end of controllable train and the stress of train coupler.*

4.2. The Use of "3+0+1" Mode Formation of Extra-Long Heavy-Duty Trains Using the Tail Locomotive Exhaust

The first extra-long heavy-duty train of Baoshin Railway started from October 12, 2009 is the "2+2" traction mode "combination train". Although the operation of the combination train has greatly improved the capacity of the capacity, but for the group of continuous hanging but increased the time. In October 2015, Baoshin Railway started the "unit train" with "Shenhua" AC locomotive hauling "3+0" grouping mode. However, this formation form is currently limited to the "Shenhua" AC locomotive, and the SS4B type electric locomotive has not yet realized the "unit train" formation mode. Therefore, the operation of "3+0+1" traction grouping mode of 10,000-ton unit trains will become the key application technology for future research.

After the "3+0+1" unit of 10,000 tons of trains, the "emergency brake control unit for extra-long heavy-duty trains" is added to the wireless reconnection control mode of locomotives, that is, the emergency control mode for extra-long heavy-duty trains is added to the original brake control unit, and this control mode can realize The control mode can control the braking machine of the tail locomotive remotely and realize the role of using the emergency valve of the tail locomotive as the air vent.

The technical focus of this solution is the remote wireless control of the traction and braking of the tail locomotive by the main control locomotive. Under the traction condition, the traction force of the front three locomotives is greater than that of the tail locomotive, and the longitudinal moment of the train is in a "stretched state"; when maneuvering on undulating slopes, the tail locomotive outputs 0 traction moment, and under the braking condition, the tail braking moment is greater than the regenerative braking moment of the front three locomotives, and the train runs in a stretched state, which can theoretically realize Theoretically, the train can be operated in a "stretched posture" throughout the whole process of ultra-long and heavy-haul trains.

The air brake wireless reconnection logic control relationship is the main car driver gate decompression, wireless reconnection control program to the tail locomotive to send a decompression command, from the tail locomotive exhaust, from back to front to apply the air braking force of the whole train, the common braking wave speed of the long heavy train "from back to front" transfer, the train is in "When relieving the train, the air braking force is relieved from the front locomotive "from front to back", and the train is in the "stretching attitude".

Emergency braking conditions wireless reconnection logic control relationship: the main control locomotive to implement emergency braking → master and slave locomotive to jump the main break off the locomotive power → tail locomotive to receive the emergency brake command from the main control locomotive → tail locomotive to produce emergency brake exhaust. According to the emergency braking wave speed, the whole train produces the emergency braking effect "from back to front" and stops smoothly with "pulling posture".

The principle of emergency braking and the force on the hook of the train in the "3+0+1" traction grouping mode is shown in Figure 4.

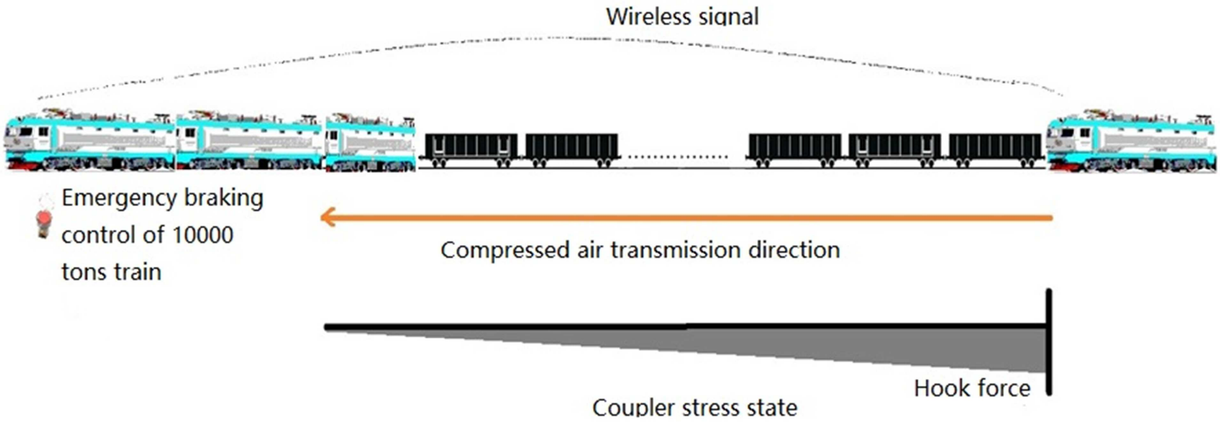

Figure 4. *"3 + 0 + 1" traction grouping mode of 10,000 tons of unit trains to implement the principle of emergency braking action.*

5. Summary

The operation of super-long heavy-load trains is the inevitable trend of the development of heavy-load freight railway transportation. Through research and analysis, it is concluded that the emergency braking of exhaust air from the tail is safer than the emergency braking of exhaust air from the head, and the dangerous compression and extrusion moment is converted into a safer pulling moment.

Change the transmission direction of the air braking torque of the super-long heavy-load train, and innovatively create the rear braking technology of the super-long heavy-load train to ensure the safe and stable operation of the super-long heavy-load train.

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