Chapter 5

Freight Speeds & HP/TL Ratio

Previous chapter highlighted the importance of increasing the freight speeds, its effect on line capacity & has touched upon many of the impediments and ground conditions in IR. The capability of freight train to run at the higher speeds and the role of locomotive power in achieving the speeds is being analyzed in detail in the present chapter. Ground condition of HP/TL ratios of freight trains in IR & impact of higher HP/TL ratios on speed, acceleration etc. will also be examined.

Why Freight Speeds are Low over IR?

Freight trains in IR have been historically running at lower speeds. Much of the advancement over the years in the rolling technology had benefitted the passenger trains in terms of the speed; however freight speeds remained moderate. Though the prescribed balancing speed[32] of the freight trains is 75 KMPH, the average speed[33] is however only 25 KMPH[34]. Most routes are

[32] Speed at which a loco can pull the loaded train on level track

[33] Average Speed: Overall speed inclusive of halts, taken from Annual Statistical Statement 2007-08 of Indian Railway

equipped with multiple aspect colour light signaling and token-less block working. The locos and wagons are designed and rated for 100 km per hour. Yet the maximum speeds of some of the freight trains are still of the order of 40-50 km per hour. Even the prescribed speed of 75 KMPH is seldom achieved in many sections.

The gross weight of a fully-loaded BOX-N is about 90 tonnes & load of the full rake is 5000 tonnes. The terrain in India on the various trunk routes is generally made up of plateaus, hilly regions and mountain ranges except for some flat section in the Gangetic Plains between Delhi and Kolkata. Almost all other routes from North to South pass through the Vindhya-Satpura ranges and the Eastern and Western Ghats. The gradient on all these routes is of the order of 1 in 100 to 1 in 400. The permissible speed on almost all rail routes is 100-120 km per hour. The passenger trains are able to achieve this speed due to their lower weight but much heavier freight trains are not able to achieve these speeds even on non-stop runs.

This is on account of the inadequate motive power hauling these trains. The balancing speed of a freight train worked by two standard diesel locomotives of WDM2 is of the order of 30-35 km per hour, implying that achieving speeds in the region of 75 km per hour is not feasible even by "two loco" operation. The recent increase of the axle load permitting CC+8+2 loading has further aggravated the situation as the trains became 11% heavier, further reducing the speeds.

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34 M. P. Sankaranarayanan (Dec 2005). Can The Railways Sweat Its Assets Better. *The Hind ,Business Line, December 23*

Role of HP/TL Ratio in Acceleration & Speeds of Trains

The most important parameter to be considered here is the HP/TL ratio: "horse power" employed per unit weight of the "train load". On IR, HP/TL Ratios vary from 0.81 to 4.51 (from 0.81 to 2.12 in the loaded direction and 2.92 to 4.51 in the empty direction). Even with the 6000HP electric locomotive, highest on IR, ratio achieved is 1.2 for a single locomotive. For the Diesel, highest 4000 HP single locomotive can give a HP/TL ratio of 0.85 only. Most of the freight trains are pulled by only single locomotive. In the case of passenger trains, horsepower to trailing load ratios vary from a high of 7.96 for a 14 coach Shatabdi Train to 3.97 for a Mail Express Train. With HP/TL ratios in the range of 4 to 5 in case of most passenger trains, it is generally possible to achieve maximum/booked speeds, starting from a stop, in 1.5 to 2 minutes, but that is not the case with freight trains where time taken in much more.

HP/TL ratio affects all the three running parameters of train i.e. **Speed, Acceleration, Braking distance**[35] & hence affects the running time, as elaborated in subsequent paragraphs.

Maximum speed & HP/TL ratio

As seen earlier, HP/TL ratio on IR hovers around 1.0 for about 50% of freight trains which cannot run at speed of 75 KMPH in gradient sections. The table 5.1 shows theoretically achievable balancing speeds in KMPH in flat and different gradient section with different HP/TL ratio. In practice speeds may be

[35] Braking distance of a train primarily depends on the type of the brakes installed in the wagons and to some extent on the locomotive control

even lower or may take very long time to achieve. Practical observations also reinforce theoretical data presented in table above.

Table 5.1 Balancing speeds in KMPH on flat & gradient section

	Gradient				
HP/TL Ratio	Flat	400	200	150	100
1	100	66	45	37	27
1.2	>100	77	53	43	32
1.4	>100	85	60	50	37
1.5	>100	90	63	53	39
1.6	>100	92	67	55	41
1.7	>100	97	70	58	43
2	>100	>100	80	66	50

(Source: derived from Power to Weight Ratio curves, Appendix II)

Acceleration & HP/TL Ratio

HP/TL ratio also determines the acceleration which train can achieve. This becomes more important in a short block section as trains may not even achieve the full speed before it needs to brake again due to lack of acceleration. If balancing speed of 75 KMPH is achieved after 30 minutes of free then it is of not practical use as it will seldom be reached & maximum speed will remain on paper. A passenger train which operates with HP/TL ratio of 5-6 is able to accelerate much faster and reach speeds of 75 KMPH in 2-3 minutes in most cases, hence will always gain passage over the freight despite its stoppages.

The acceleration distance graph taken from a study of American Railways (figure 5.1), shows the wide variance in the distance travelled till the desired speed is reached. Condition at IR may vary depending on the rolling stock and terrain but trends are going to be samilar.

For a freight train of HP/TL Ratio of about 1.2 it will take about 10 Minutes to reach the desired speed of 75 KMPH, whereas with lower HP it takes much longer upto 30 minutes. Unless freight train has long free run it cannot realize the full speed potential it is capable of.

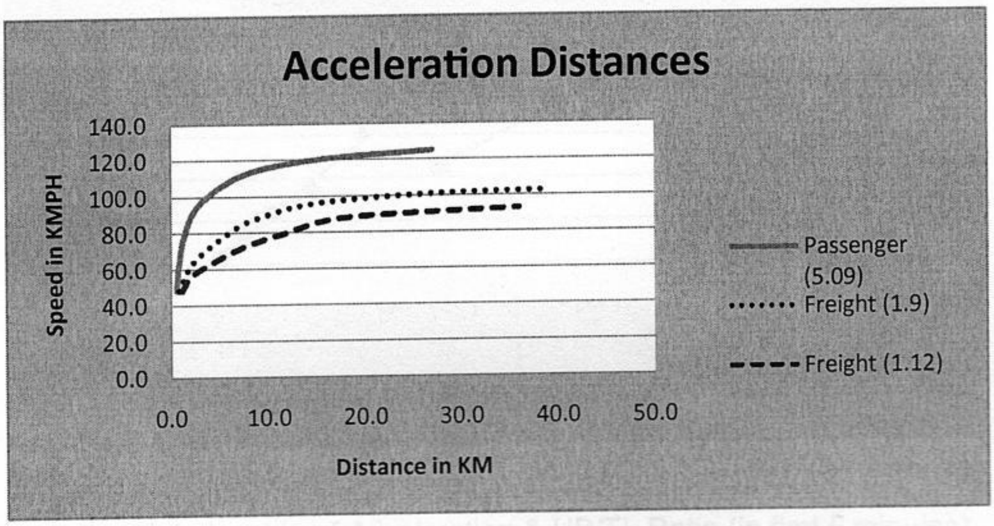

Figure 5.1 Acceleration Distance Curve at Different HP/TL Ratio of Passenger & Freight trains. The figures in brackets indicated HP/TL ratio.
(Source: adapted from study from American Railroad Appendix III)

Braking distance though has no direct relation with HP of the locomotive but a higher powered locomotive is normally designed to provide higher re-generative braking. Due to the lighter train load, a passenger train with the same speed has much less braking distance.

Correlation between HP/TL Ratio & Acceleration

It was also explored whether there is any direct correlation between acceleration and HP/TL ratio of the trains. For this purpose average acceleration of electric locomotive, in first 5 minutes of run, which is vital for the speed potential, was plotted against HP/TL ratio & Acceleration. The acceleration in first 5 minutes is found to have a near linear relationship with the HP/TL ratio as depicted by the graph (figure 5.2).

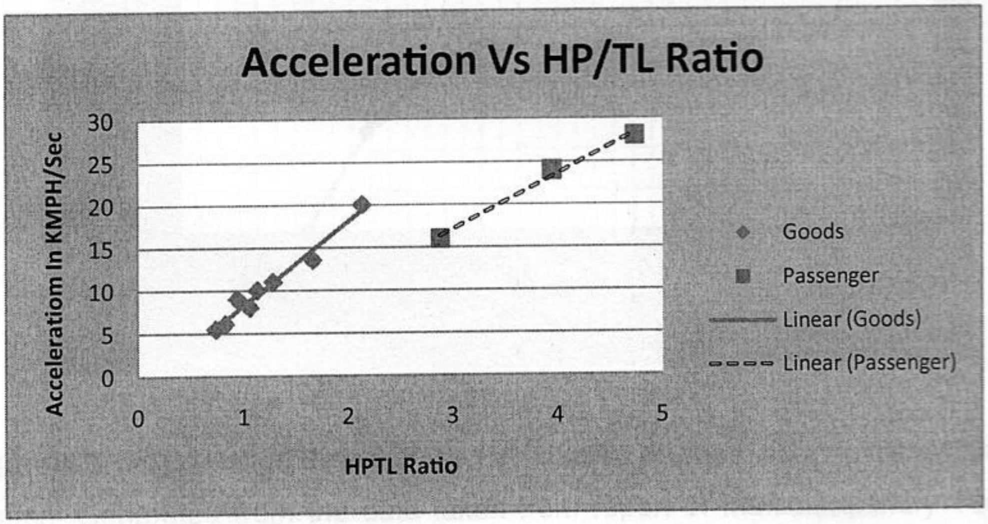

Figure 5.2 Relationship of Acceleration & HP/TL Ratio (in first 5 minutes)
Source: Drawn from the data taken from speed curves of different locomotives (Data at Appendix V)

HP/TL Ratio & Running Time

A LRDSS[36] multidisciplinary team has done an analysis of the effects of horsepower to trailing load ratio (HP/TL) through software simulation on the Mughalsarai - Sonnagar section. These studies indicated that the correlation

[36] Long Range Decision Support System, an unit of Railway Board, MOR

between the HP/TL ratio and transit time (free running time) is of the order of 0.98[37]. However, this correlation was found to be valid only within a certain range, specifically, up to a value of 1.5 for the HP/TL ratio. Increasing this ratio beyond 1.5, on flat terrain, was not found to show any commensurate decrease in free running times (figure 5.3).

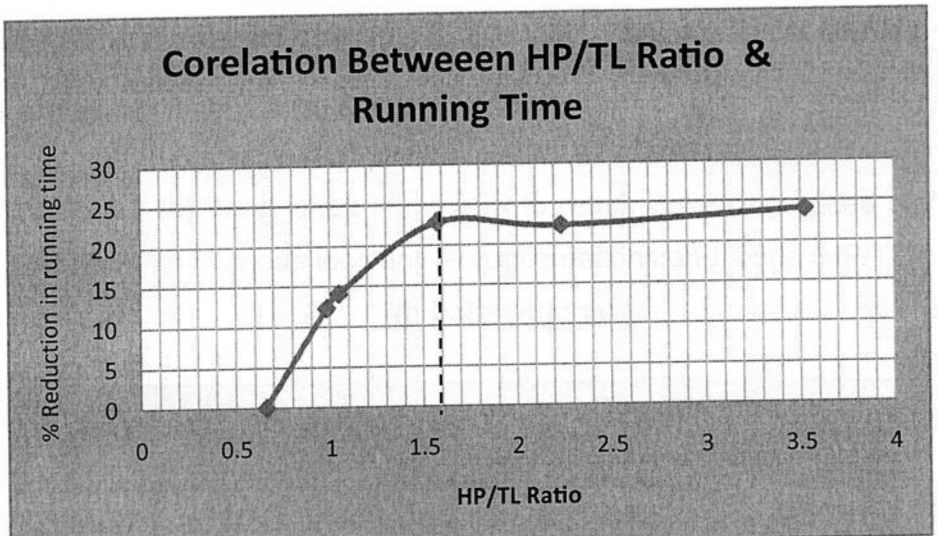

Figure 5.3 Correlation between the HP/TL ratio and reduction in transit time. Source: Generated from the data taken from report of Multidisciplinary Team on Throughput Enhancement (Data At Appendix VI)

The percentage reduction in time have been plotted against HP/TL Ratio which indicates the good improvement upto 25% in running time of the fully loaded trains in flat section. The findings should not be interpreted that there will not be any gains beyond 1.5 but the gains beyond 1.5 are limited by other factors or will be more significant in sections with gradient.

37 Multidisciplinary Team. Throughput Enhancement Report of the, Railway Board, MOR

Analysis of Locomotive Speed Graphs

Analysis of the various locomotive speed graphs & data generated by RDSO was done to establish a clear picture about the time taken to reach balancing speeds for a goods train with various locomotive configurations in IR. Tables 5.2 (a) & 5.2 (b) give the time taken to reach speeds of 75 KMPH and 100 KMPH in different gradients & give their acceleration capabilities. The results are as per table 5.2 (a) & (b).

Table 5.2 (a) Time taken in minutes to reach Balancing speed of 75 & 100 KMPH by various locomotive configurations and loads (HP/TL)

In flat sections

Loco	Load	HP	HP/TL ratio	Time in Minutes	
				75 KMPH	100 KMPH
2WAG7	4700	10000	2.13	4.70	9.50
2WAG5	4700	7800	1.66	6.81	N.A.
1WAG9	4700	6000	1.28	8.30	17.00
1WAG7	5294	6000	1.13	9.55	22.50
GM	5294	5000	0.94	12.47	
WAG5	4700	6000	1.28	19.76	
WAG5H	5062	3900	0.77	22.00	
WDG4	5294	3900	0.74	27.39	
WDM2	5294	4000	0.76	27.72	
WDG2	5062	3100	0.61		
WDG2	5062	3100	0.61		

Source: Data taken from the Locomotive Speed Curves of RDSO,

(Appendix IV)

Table 5.2 (b) Time taken in minutes to reach Balancing speed of 75 & 100 KMPH by various locomotive configurations and loads (HP/TL)

In 500 & 200 Gradient

Loco	Load	HP	HP/TL ratio	Time in Minutes	
				75 KMPH	100 KMPH
1 in 500 Gradient					
2WAG9	5294	12000	2.27	5.21	10.68
2WAG7	5294	10000	1.89	6.86	
2WAG5A	5294	7800	1.47	15.97	
2WAG5H	5294	7800	1.47	15.19	
2WDG4	5294	4000	0.76	16.16	
2WDG2	5294	3100	0.59		
1 in 200 Gradient					
2WAG9	5294	12000	2.27	10.14	

Source: Data taken from the Locomotive Speed Curves of RDSO, (Appendix IV)

The blank boxes in tables show those cases where speed is not achievable. As we can see that for HP/TL ratios below 1, time taken to reach 75 KMPH is beyond 12 minutes even for the flat section. Even with 2 locomotives and HP/TL ratio of 1.47, it takes about 15 minutes to reach that speed in a moderate 1 in 500 gradient. For the steeper gradient of 1 in 200, balancing speed of 75 is not possible except for 2WAG9 locomotives (2.27 HP/TL). If IR has to achieve these speeds in all conditions than HP/TL Ratio will have to be improved beyond 2.0 by augmenting locomotive power. In worst case HP/TL ratio of 1.5 or more has to be maintained in all cases for a reasonable acceleration time.

Summary

The three important parameters of a train running: speed, acceleration & braking, determines the time it is going to take to clear the section and finally the line capacity. The effect of increasing HP/TL ratio on these parameters acceleration, maximum speed, acceleration distances & time to achieve the speeds were examined in details from simulation studies/speed graphs. Direct correlation was found to exist between HP/TL ratio and these parameters & benefit of deploying higher HP/TL ratio was clearly observed.

In IR HP/TL ratio are in the vicinity of 1.0 and hampers the acceleration, maximum speed & time taken to achieve the desired speed. It was observed that freight trains in India are much behind the passenger trains which has healthy HP/TL ratio of 4-5 and thus cannot match them in running performance. The HP/TL ratio table of the locomotives in IR revealed that in majority of the cases prescribed speeds are not achieved in gradient section or take very long time. From the analysis it became clear that HP/TL ratio need to be improved beyond 1.5 and preferably brought near to 2 if speeds and acceleration has to be improved to desired level.