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Aerodynamic Phenomena Caused by the Passage of a Train. Part 5 – Slipstream Influence on People

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Summary

In the series of articles describing the aerodynamic phenomena caused by the passage of a train, the effects of a train running at high speed on itself, on other trains, on objects on the track and on people are characterized. This impact can be of two types – generated pressure and slipstream. Apart from the literature analysis, the author's research is also taken into account. The fifth part of the series describes the impact of the slipstream on people.

Keywords: rolling stock, high speed railways, aerodynamic phenomena

1. Introduction

The first part [1] discussed a general classification of aerodynamic phenomena, divided into pressure changes and slipstream by the type of influence. It also presented changes of pressure in the open air, caused by a train passage, and the influence of pressure on various objects located near the track. Primary normative documents concerning aerodynamic issues were specified as well. It also depicted conclusions on the construction of a high-speed railway vehicle, as well as durability and location of the structure at high-speed lines.

The second part [2], which continued issues regarding pressure changes, focused on the mutual influence of moving trains on their front and side surfaces. It was concluded that it is the high-speed train that influences the slower train and other objects, not the other way round. The consequence of this is a significant – even over 6 times – rise in the pressure on the windscreen of an older train with a maximum speed of 120 km/h, passing a train running at 350 km/h, which may entail the risk of damaging the windscreen of the rolling stock with a lower maximum speed.

The third part [3] is devoted to slipstream, which is the second, in addition to pressure, main type of aerodynamic influence caused by a train passing at high speed. The characteristic features of the slipstream and its influence on the environment (in the form of forces acting on objects) and railway infrastructure were described. A comparison of the slipstream caused by a standard train (made up of a locomotive and carriages) and high-speed multiple units is presented, from which it is clear that multiple units create a much smaller slipstream and can run at higher speeds due to this type of influence. Mixed aerodynamic influence (i.e. the combined, simultaneous influence of pressure and slipstream) that can cause the breakstone to be picked up by the "suction" of the pressure and the entrainment of the breakstone by the slipstream wave are also discussed and illustrated with pictures.

The fourth part [4] focused on the issue of pressure impact on people – both railway workers and passengers waiting on platforms and standing near open windows or sitting near the window in passing trains.

This part of the series of articles addresses the impact of slipstream on people, which – similar to the impact on surrounding objects – is the second type of aerodynamic impact, apart from pressure, induced by the passage of a train at high speed.

2. Slipstream Influence on Passengers or Railway Workers

As indicated in the introduction, slipstream is the second type of influence, apart from pressure, on passengers or railway workers who are in the vicinity of

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a track when a train passes at high speed. The section 6.2 of the standard PN-EN 14067-4 [5] states that it is the dominant type of influence affecting people. The speed of the slipstream, apart from the geometry of the train itself, is also significantly influenced by the geometric layout of the track and its surroundings. The slipstream induced by a passing train creates forces that act on both objects and people. The speed and direction of the resulting slipstream change abruptly during the train's passage. For individuals, there is a risk of temporary loss of balance, which in extreme situations can even lead to falling over.

The safety issues related to the occurrence of slipstream were also highlighted in the report [6]: "Consequently, with trains traveling at high speeds passing some train stations without stopping, the airflow from the passing train can affect the safety of people waiting on the platform. An incident reportedly occurred in Ventura, California, where an empty stroller on a train station platform was propelled toward the track, presumably by the airflow induced by the passing train, crushing the stroller under the train's wheels (Freedenberg 2003 [7]). Numerous incidents have occurred on station platforms in Britain caused by train-induced airflow that included: a luggage barrow and children's pushchairs being set into motion and hitting the train, and people almost losing their balance from a passing train (Gawthorpe 1994 [8]; Johnson, Dalley, and Temple 2002 [9]). Passing freight trains have caused most of the incidents in Britain (Temple and Johnson 2003 [10]). In addition to station platforms, safety issues have been raised in the United States on the aerodynamic effects from passing trains on people using RWT where shared-use trails (trails for pedestrians and bicyclists) are developed and located adjacent to active rail lines."

To assess the effects of the slipstream on passengers or railway workers, the same values apply as for the vehicle assessment, which were described in section 2 of part three [3] of the series. For reference, at a distance of 3 meters from the track axis, where the train is passing, the slipstream should not exceed:

- 15.5 m/s at a height of 1.4 m above the rail head,
- 20 or 22 m/s at a height of 0.2 m above the rail head, depending on the maximum speed of the train.

To better understand the magnitude of these values, we can relate them to the description of wind strength in the Beaufort scale. Table 1 presents numbers from the Beaufort scale corresponding to the respective permissible slipstream values, along with the associated wind speeds and descriptions.

Long before the establishment of the standard PN-EN 14067-4 [5], the author of a study [13] conducted by the Railway Research Institute (then Central Centre for Research and Development of Railway Technology), while examining aerodynamic phenomena, suggested: "At a wind force of 7° on the Beaufort scale (17 m/s) on station platforms, where a high-speed train is passing, people should not be present." The same recommendation was repeated in the final conclusions. The author recommended 12 m/s (a moderate 6 on the Beaufort scale) as the maximum human-acceptable velocity of the airstream in a slipstream, and based on this he determined the boundary of the danger zone as a function of train speed. This is shown in Figure 1 (tests were conducted up to 200 km/h and extrapolated to 300 km/h).

Table 1

Comparison of slipstream and wind force in the Beaufort scale (B) [Authors' own elaboration based on [11, 12]

Permissible slipstream according to the standard [m/s]	B	Wind speed [m/s]	Description	Land conditions
–	4	5.5÷7.9	moderate breeze	raises dust and loose paper; small branches moved
–	5	8.0÷10.7	fresh breeze	small trees in leaf begin to sway
–	6	10.8÷13.8	strong breeze	large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty
15.5	7	13.9÷17.1	near gale	whole trees in motion; inconvenience felt when walking against the wind
20.0	8	17.2÷20.7	gale	twigs break off trees; generally impedes progress
22.0	9	20.8÷24.4	strong gale	slight structural damage

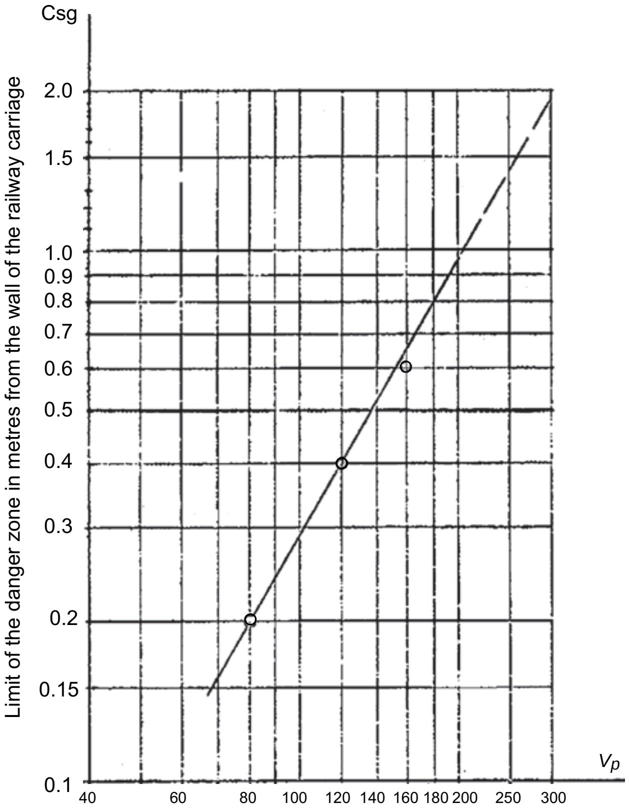

Fig. 1. Boundary of the Human Danger Zone According to K. Kubski [13]

From the descriptions presented in Table 1, it is evident that the permissible slipstream values specified in the standard PN-EN 14067-4 [5] are dangerous for both passengers standing on platforms and for railway workers performing tasks on the tracks. Consequently, a distance of 3 metres from the track centre – corresponding to a distance of over 1.3 m from the rolling stock gauge and also from the edge of the platform (as a reminder – at torso height there is only a 30 mm difference between them) and about 1.5 m from the train wall – is too small. Passengers on a standard platform with a height of 0.76 m (according to TSI INF [14]) will be exposed to slipstream forces of 7 degrees on the Beaufort scale at torso height and potentially stronger – even up to 9 degrees on the Beaufort scale at leg height, with the impact at leg height posing a lesser danger than at torso height. Meanwhile, due to the terrain configuration, railway workers may be exposed to slipstream forces of up to 9 degrees on the Beaufort scale, also at torso height. Additionally, the train speed for which the slipstream limits were given must be considered. The slipstream value at a height of 1.4 m – mainly concerning persons on the platform – is measured at a train speed of 200 km/h (or less, if the train does not reach such a speed). Hence, trains capable of reaching significantly higher speeds, e.g., 350 km/h, can generate a considerably greater slipstream at a distance of 3 m from the track centre (i.e., about 1.3 m from the platform edge) than the standard indicates. The slipstream value at a height of 0.2 m – and thus acting on railway workers in the field and partly on people on the platform, at leg height – is determined differently. The slipstream in this case is measured at a train speed of 300 km/h. Therefore, for a train reaching a speed of 350 km/h, the generated slipstream will not be significantly greater. This is based on permissible slipstream values, though the actual slipstream for a specific type of railway vehicle may be significantly lower. However, it cannot be ruled out that a vehicle that generates a slipstream close to the threshold value will be approved for operation in the future. Therefore, it is necessary to aim to limit the magnitude of the slipstream for passengers, at least by 1÷2 degrees on the Beaufort scale (to values of 5÷6 B) and by 2÷3 degrees for railway workers (to values of 6÷7 B). Allowing a slightly greater slipstream impact on railway workers seems justified, considering that they are typically adults (aged 18 to 65) and fully able, which may not necessarily be the case with passengers (who can also be children, the elderly, or persons with reduced mobility).

Reducing the size of the slipstream can be achieved either by reducing the speed of trains when passing platforms on which they will not stop, or by increasing the distance from the track centre (wall of the train) for passengers and railway workers, or by constructing platforms that are not directly adjacent to the main tracks (extensions of the plain line tracks), but next to subsidiary tracks, so that trains not stopping at platforms are separated from them by an additional track. This approach is also reflected in Polish legislation. In the regulation [15], concerning the location of railway structures (Article 98, section 4a), it states: "Platforms shall not be located next to tracks on which trains run at a speed higher than 200 km/h, except where technical and operational measures are in place to ensure access from the platform to the train only when the train is stopped." Since the positioning of a platform next to the main tracks is not entirely excluded, efforts should be made to ensure a sufficiently wide inaccessible zone for passengers, preferably combined with a warning system informing about an approaching train and whether it stops at the station.

Assuming a reduction of the slipstream, from the 15.5 m/s allowed by the standard PN-EN 14067-4 [5] at a distance of 3 m from the track centre to a value in the middle of the air velocity range at 5 degrees on the Beaufort scale, i.e., 9 m/s, the result is a 1.7-fold reduction in wind speed. The slipstream curves for the different vehicles presented in Figure 8 of part three [3] can be used to find the distance at which the slipstream reaches the assumed velocity. Assuming for simplicity that the width of the rolling stock is 3.0 m (the average actual widths of Polish passenger carriages are up to 2.88 m), then for a distance of 3 m from the track centre (i.e. about 1.5 m from the side wall of the train), we read from the chart the dimensionless slipstream values relative to velocity and, after dividing by the coefficient of 1.7, we read the new safe distance for such calculated ratios. The results are presented in Table 2.

The "small induced slipstream" curve, the lowest on the chart, was used as the theoretical curve, as for the other curves the recalculated new values would be off the chart. Furthermore, one curve representing theoretical calculations is entirely sufficient in this situation, as all three curves are derived from the same calculations. In the case of the 103 DB locomotive, for which the new recalculated value would also have been off the chart, the character of this curve raises doubts – its noticeable flattening would imply almost a complete lack of attenuation (fading) of the slipstream, with a zero value being reached at a distance of several tens of metres. Excluding this curve yields an average value of 3 m, measured from the side of the vehicle, that is approximately 4.5 m from the track centre. This value is approximately 0.7 m less than the proposed prohibited zone for hearing protection in the vicinity of fixed objects of approximately 5.2 m from the track centre, as shown in Figure 4 in part four [4].

Regarding Polish track workers, Technical Standards [18] apply, according to which the danger zone, in which workers cannot stay for train speeds of 160 km/h < $V \leq$ 250 km/h, is 3.0 m (nominal value; there are also narrower and exceptionally permissible values). This value is calculated based on the standardised structure gauge GPL-1, the edge of which is 2 m from the track centre. Therefore, track workers should not be closer than 5.0 m from the track centre. It therefore seems reasonable that passengers on the platform should also be kept at least 5 m from the track centre (more than 3.3 m from the edge of the platform), especially as the designated zone for workers applies to speeds of no more than 250 km/h.

A similar approach by British Railways in terms of differentiating permissible slipstream speeds for passengers and workers was mentioned in the report [17]: "In terms of the level of induced airflow exposure for people on station platforms, British Rail suggested a limit for lineside workers of 38 mph which corresponds to the upper end of the Beaufort Scale Number 7. For members of the public, the suggested limit is 25 mph, which corresponds to the upper end of Beaufort Scale Number 5." Based on this, American Railways made an assessment of speed limitations for trains concerning passengers and workers located at a distance of 1 m or 2 m from the train (Table 3). The given speed ranges result from different aerodynamic properties characterising various train formations.

Table 2

Recalculation of slipstream values and finding the new safe distance

Slipstream source	Chart values for 1.5 m	Divided values (:1.7)	New distance [m]
Conventional train	0.25	0.15	3.1
Theoretical curve "small induced slipstream"	0.29	0.17	4.1
BR 86 train, slipstream at a height of H = 1.75	0.30	0.18	2.5
BR 86 train, slipstream at a height of H = 0.81	0.38	0.22	2.47
103 DB locomotive	0.39	0.23	off scale
Russian train with a flat front	0.40	0.23	3
average			**3.0**

[Authors' own elaboration based on 16, 17].

Table 3

Reduction of train speed for limiting slipstream at a distance of 1 and 2 m from the train [17]

Wind force criterion	V_{max} for 1 m from the train [km/h]	V_{max} for 2 m from the train [km/h]
5 degrees on the Beaufort scale (passengers)	80÷118	98÷146
7 degrees on the Beaufort scale (workers)	127÷188	156÷232

Table 4 presents the values of slipstream induced on platforms by trains passing on the route from New Haven (Connecticut) to Boston (Massachusetts). Similarly to Table 3, the speed ranges result from different aerodynamic properties of the trains. Although the height above the rail head at which the slipstream was measured is not specified, some of the obtained values exceed the permissible European values from the standard PN-EN 14067-4 [5], provided for a distance of 3 m from the track centre, which is about 1.5 m from the train (for the train speeds mentioned here, this is 20 m/s at a height of 0.2 m and at a speed of 200 km/h or the maximum operational speed – 15.5 m/s at a height of 1.4 m).

The report [17] also includes an analysis of the impact of slipstream conducted by the Swedes [19]. Two dummies were placed on a platform at two distances from the track centre – 3.2 m and 4.3 m. The most unfavourable case of people facing or with their backs towards the oncoming train was simulated – the bodies had an area of 0.73 m^2 in the plane perpendicular to the track centre and 0.36 m^2 in the plane parallel to the track centre. Wind force was measured during 32 passes for three different types of trains: a freight train, an IC express train, and a high-speed X2000 train. Measurements were made in various wind conditions and at different train speeds. The results of the arithmetic averages of the maximum resultant forces are shown in Table 5.

The report [6] presents the results of a study carried out in 2002 by SNCF staff in Mansfield, Massachusetts. The study was carried out using cylindrical dummies (SNCF/VR Model 1993) that imitated the human silhouette, consisting of cylinders with a diameter of 0.39 m and a length of 0.92 m, mounted on strain gauge-equipped posts with a base (Figure 2). The compilation of the results is presented in Table 6.

Table 4

Slipstream speed induced by passing trains [17]

Train speed	Slipstream at 1 m from the train	Slipstream at 2 m from the train
161 km/h	14.7÷21.7 m/s (53÷78 km/h)	11.9÷17.5 m/s (43÷63 km/h)
241 km/h	21.9÷32.2 m/s (79÷116 km/h)	17.8÷26.4 m/s (64÷95 km/h)

Table 5

Table 5 Arithmetic averages of maximum resultant forces [17]

	IC train	Freight train	High-speed train $V < 200$ km/h	High-speed train $V > 200$ km/h
Dummy at 4.3 m from the track centre*	62 N	96 N	59 N	114 N
Dummy at 3.2 m from the track centre**	139 N	154 N	103 N	261 N
Maximum pulling (suction) force at 3.2 m from the track centre**	88 N	65 N	90 N	126 N
Maximum pushing force at 3.2 m from the track centre**	101 N	101 N	88 N	208 N

*) 4.3 m from the track centre corresponds to 2.76 m from the wall of a high-speed train
**) 3.2 m from the track centre corresponds to 1.66 m from the wall of a high-speed train

Table 6

Passenger impact forces for nominal train speeds [6]

Train type	Resulting force (mean + 2σ)			
	Dummy axis 1.2 m from the train		Dummy axis 1.46 m from the train*	
	201 km/h	241 km/h	201 km/h	241 km/h
Acela Express	74 N	106 N	63 N	91 N
Amfleet train with AEM-7 locomotive	174 N	–	119 N	–
Amfleet train with HHP-8 locomotive	129 N	–	insufficient measurements	–

*) – 1.46 m corresponds to the safe distance in France for railway workers near high-speed tracks (with TGV trains travelling at speeds greater than 209 km/h and conventional trains travelling at speeds greater than 161 km/h).

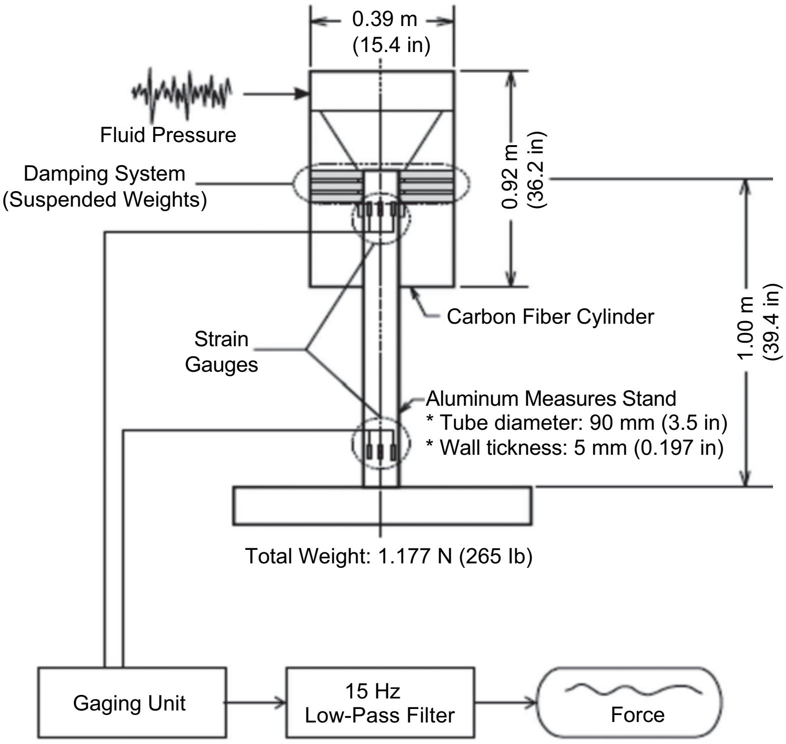

Fig. 2. SNCF/VR Model 1993 dummy for the measurement of forces acting on humans [6]

The Acela Express is a typical high-speed electric multiple unit with tapered noses at each end (V_{max} = 240 km/h). Amfleet type carriages are conventional passenger carriages with a flat end, designed to be pulled by a locomotive (V_{max} = 201 km/h). The AEM-7 locomotive is an older type of electric locomotive with a flat front (V_{max} = 201 km/h). The HHP-8 locomotive is an electric locomotive with a slightly elongated front (V_{max} = 217 km/h). The results presented in Table 6 fully correspond to the shapes of these locomotives.

The partial results are shown in Figures 3–6 with detailed indication of which train and which part of it generates the slipstream of a certain force:

- "Head" – the area around the front, encompassing the phenomena just before the train to the passage of the front of the train;
- "Tail" – the entire train excluding the head and the space behind the train where air masses are pulled along with the train;
- "Wake" – the space behind the train where air masses are pulled along with the train;
- "Train" – the entire length associated with aerodynamic phenomena caused by the passing train.

The vertical axis presents the forces related to the speed of the train (quotient of force to train speed $\cdot 10^{-4}$).

Figures 4 and 6 demonstrate clear differences between trains – the uniform impact of slipstream forces generated by high-speed trains (electric multiple units with tapered noses) and the very uneven impact of slipstream forces generated by classic trains – composed of a locomotive and carriages. For this reason, trains specifically designed for high speeds can travel much faster, causing the same level of slipstream as slower-moving older generation trains with flat-front locomotives. These studies also show that it is easier to achieve desired aerodynamic effects on a uniform vehicle like a multiple unit train.

The studies conducted by the author regarding the slipstream generated by Polish rolling stock, as described in part three [3], led to exactly the same conclusions that the aerodynamic shape of the vehicle is crucial for the generated slipstream. In this regard, the bodies of multiple unit trains are much better shaped, with possibly well-shielded chassis and bogies, causing milder impact than classic trains, composed of a locomotive and attached carriages. Classic rolling stock, on the other hand, lacks such shielding entirely or only has it to a limited extent, leading to the movement of larger air masses and causing greater air turbulence. This refers both to the generation of the slipstream itself in the form of "wind" and to the forces it generates.

The studies conducted on dummies [6] also showed that although the impact of a passing train is turbulent (especially in the area behind the train), the dominant direction of air flow is that of the passing train. The impact on people mainly occurs in the longitudinal direction, and the transverse impact is

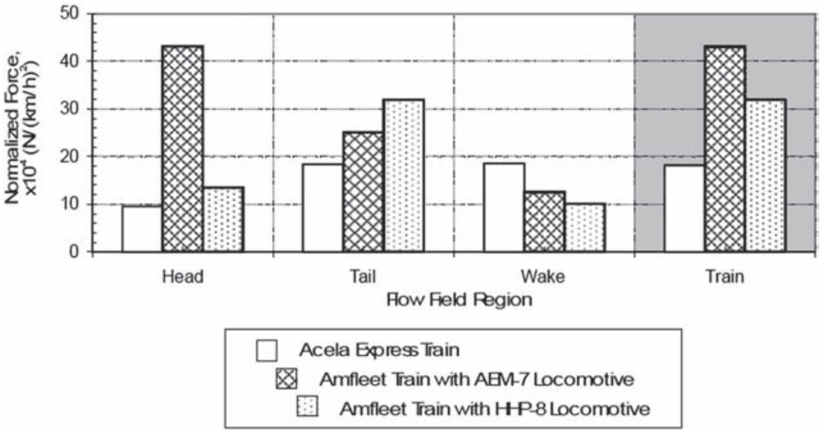

Fig. 3. Forces acting on the dummy at a distance of 1.2 m from the train by zones [6]

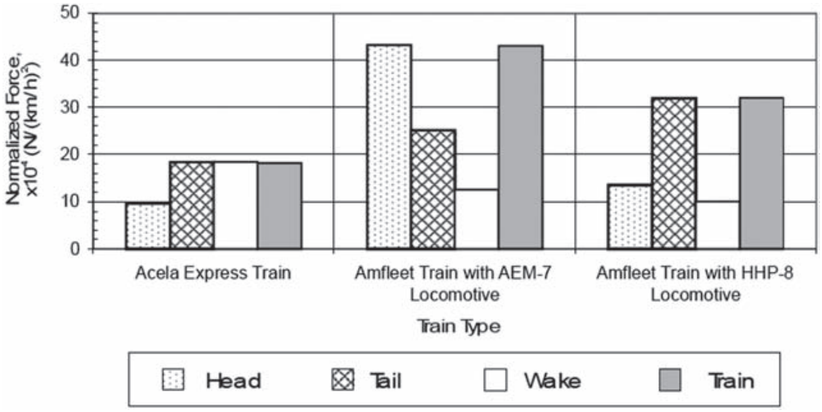

Fig. 4. Forces acting on the dummy at a distance of 1.2 m from the train by train type [6]

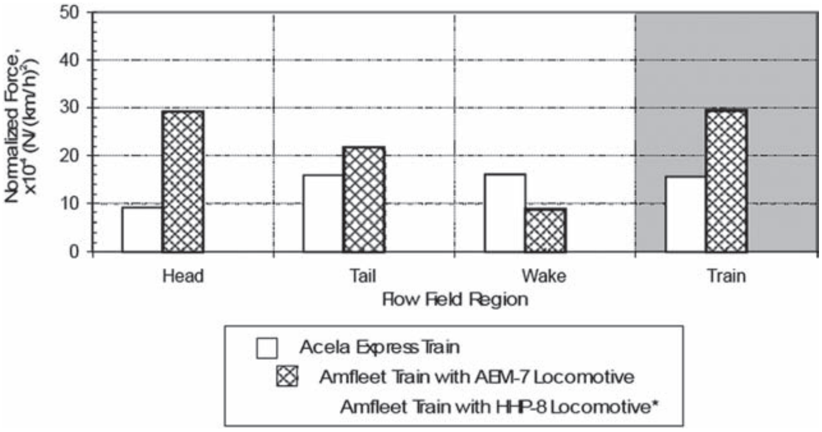

Fig. 5. Forces acting on the dummy at a distance of 1.46 m from the train by zones [6]

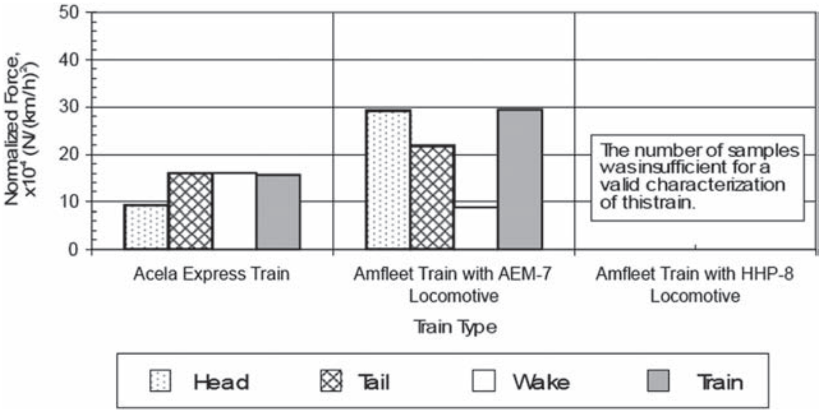

Fig. 6. Forces acting on the dummy at a distance of 1.46 m from the train by train type [6]

not significant, except in the case of a train with a flat front, where there is a strong lateral slipstream. The force of impact on passengers (dummy) is similar for all trains and is as follows:

- for the longitudinal direction: during the passage of the train's front, the passenger is first pushed in the direction of the train's movement, followed by an immediate pull in the opposite direction, and during the passage of the rest of the train, the passenger is mainly pushed in the direction of the train's movement;
- for the transverse direction: during the passage of the train's front, the passenger is initially pushed away from the train and then pulled towards it, and during the passage of the rest of the train, the passenger is alternately pushed and pulled, oscillating around a neutral position.

As a result of studies conducted from the level of a low platform (8 inches or 203 mm above the rail head) on Acela Express passenger trains (V_{max} = 240 km/h) and Amfleet carriages with AEM-7 (V_{max} = 201 km/h) and HHP-8 (V_{max} = 217 km/h) locomotives, the report [6] proposed the following minimum distances from passing trains (Table 7).

Table 7

Recommended minimum distances [6]

	Distance from the centre of the track [m]	Distance from the train [m]
Passenger on the platform	3.12	1.6
Railway worker at the side of the track	2.72	1.2

In Poland, there are two types of high-speed passenger trains:

- the ED250 electric multiple unit (Pendolino), capable of travelling at a maximum operational speed of 250 km/h,
- the EU44 Husarz (Eurosprinter ES64U4 Taurus) locomotive with passenger carriages, capable of travelling at a maximum operational speed of 200 km/h (according to [20], the maximum speed of the ES64U4 locomotive is 200 km/h with direct current power supply and 230 km/h with alternating current power supply).

Table 8 presents the results of the author's previous studies conducted on these trains. The results of the studies are indicative, as they did not concern the authorisation of a specific type of railway vehicle for operation and therefore 20 runs at specific speeds were not carried out. Some of the study results have been recalculated to the speeds required by the standard. However, they reliably show the values of the generated slipstream at a distance of 3 m from the track centre.

On the basis of the author's studies, it can be concluded that for these trains the postulated condition of reducing the slipstream to 5÷6 B for passengers and to 6÷7 B for railway workers is met. Assuming that passengers are mainly affected by the slipstream at a height of 1.4 m above the rail head, at a distance of 3 m from the track centre, neither the Husarz locomotive pulling passenger carriages nor the Pendolino, even at a speed of 250 km/h, exceeded the value of 5 degrees on the Beaufort scale (during vehicle approval, the tests would be conducted at a maximum speed of 200 km/h, for which the slipstreams are even smaller). As for workers, who are exposed to slipstream not only at a height of 1.4 m above the rail head but also at a height of 0.2 m, for both these trains, the value of 6 degrees on the Beaufort scale was not exceeded. Although these results do not consider the impact of wind in the environment and specific terrain conditions that might affect the measurement outcomes, it can be stated that for the currently operating high-speed trains in Poland, a distance of 3 m from the track centre (1.325 m from the platform edge) is a sufficient safety zone in terms of slipstream impact. This is consistent with the danger zone of 1.5 m from the platform edge set by Regulation [15] (Art. 98, sec. 11) for train speeds up to 200 km/h.

In line with earlier considerations regarding the determination of a safe distance from the track (train) for passengers and track workers, for the speeds of 250-350 km/h achieved by new trains, a distance of 5 m from the track centre should be maintained, until the slipstream they generate is experimentally confirmed.

3. Conclusions

Both the studies described in the cited foreign literature and the research conducted by the author on Polish rolling stock demonstrate that the aerodynamic shape of a vehicle significantly affects the generated slipstream and the forces it creates. High-speed multiple units, with their aerodynamically superior design compared to classic rolling stock (locomotive and attached carriages), are notably more efficient in this regard. These high-speed trains feature well-shielded chassis and bogies, as well as a uniform, sleek body ending in tapered noses on both ends, resulting in milder aerodynamic effects. Classic rolling stock, on the other hand, lacks such shielding entirely or only has it to a limited extent, leading to the movement of larger air masses and causing greater air turbulence.

The studies described in this part also showed that the predominant direction of airflow is that of the passing train. Therefore, the impact on people is mainly in

Table 8

Slipstreams at a distance of 3 m from the track centre

Slipstreams [m/s] at a distance of 3 m from the track centre at heights of 0.2 and 1.4 m, related to the wind force on the Beaufort scale from Table 1				
Husarz locomotive, speed 200 km/h, 11 measurements				
	h = 0.2 m	Beaufort degree	*h* = 1.4 m	Beaufort degree
Maximum value	13.6	upper 6	10.2	upper 5
Average value	10.5	upper 5	7.9	upper 4
Average + 2sigma	13.4	upper 6	10.6	upper 5
Pendolino, speed 200 km/h, 6 measurements				
	h = 0.2 m	Beaufort degree	*h* = 1.4 m	Beaufort degree
Maximum value	9.4	average 5	8.0	lower 4
Average value	7.0	average 4	6.6	average 4
Average + 2sigma	10.6	upper 5	8.8	average 5
Pendolino, speed 250 km/h, 8 measurements				
	h = 0.2 m	Beaufort degree	*h* = 1.4 m	Beaufort degree
Maximum value	10.9	lower 6	9.8	average 5
Average value	9.3	average 5	7.6	upper 4
Average + 2sigma	12.2	average 6	10.4	upper 5

[Authors' own elaboration].

the longitudinal direction, and the transverse impact is not significant. Only in the case of trains with a flat front is there a strong lateral slipstream, but such trains do not operate at high speeds. The authors of the various studies analysed in this article indicate that a wind force of 7 on the Beaufort scale (i.e. up to 17.1 m/s) can be dangerous for people. Therefore, it is necessary to aim to limit the magnitude of the slipstream for passengers, at least by 1÷2 degrees on the Beaufort scale (to values of 5÷6 B) and by 2÷3 degrees for railway workers (to values of 6÷7 B).

Reducing the size of the slipstream can be achieved by reducing the speed of trains when passing platforms where these trains will not stop. However, such a procedure is contrary to the idea of increasing train speeds – it is not intended to be raised only to later be limited. Therefore, other ways must be found to limit the dangerous impact of slipstream on passengers and railway workers. This can be achieved by other means such as:

- limiting the presence of people on platforms through which a train passes at high speed,
- increasing the walking distance from the track centre (train wall), e.g. by providing a sufficiently wide area not accessible to passengers, preferably in combination with a warning system informing about an approaching train and whether the train is stopping at the station,
- constructing platforms that are not directly adjacent to the main tracks (extensions of the plain line tracks), but next to subsidiary tracks (main auxiliary tracks), so that trains not stopping at platforms are separated from them by an additional track.

For the currently operating high-speed trains in Poland, a distance of 3 m from the track centre (1.325 m from the edge of the platform) is a sufficient safety zone in terms of slipstream impact and meeting the proposed condition of reducing the slipstream to values of 5÷6 B for passengers and to values of 6-7÷B for railway workers. At a height of 1.4 m above the rail head (the main level of impact on passengers), at a distance of 3 m from the track centre, neither for the Husarz locomotive pulling passenger carriages nor for the Pendolino was the value of 5 degrees on the Beaufort scale exceeded. Whereas for railway workers who are also exposed to slipstream 0.2 m above the rail head, the Beaufort value of 6 was not exceeded for both of these trains.

For potential new trains reaching speeds of 250–350 km/h, until the slipstream they generate is experimentally confirmed, a distance of 5.0 m from the track centre should be maintained.

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