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P1_1 A New Form of Public Transport: The Pneumatic Tube Train

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Abstract

Public transport via a system of pneumatic tubes is discussed and the physical principles surrounding its operation are outlined. The safety considerations inherent in such a design are briefly assessed and initial safe operating parameters are suggested.

Introduction

In 1882 Albert Robida published his speculative science fiction novel 'The Twentieth Century' [1] in which he discussed a novel form of public transport- the pneumatic tube train. The concept of a train driven by compressed air or a vacuum has been popular amongst many other authors over the years and sparked the imagination of engineers who attempted to implement such systems [2], although without much success. In the 21st century public transport is of particular interest as the world faces climate change, in part due to damaging gases emitted by more personal forms of transport such as cars. This article discusses the physical principles behind a vacuum driven pneumatic tube train similar to that proposed by Robida 127 years ago.

The Tube Train

Taking a simple model, based upon Robida's sketches, the pneumatic tube train would consist of a long tube within which a cylindrical carriage sits, as is shown in figure 1. To ensure the carriage remained on course it would travel along a set of rails.

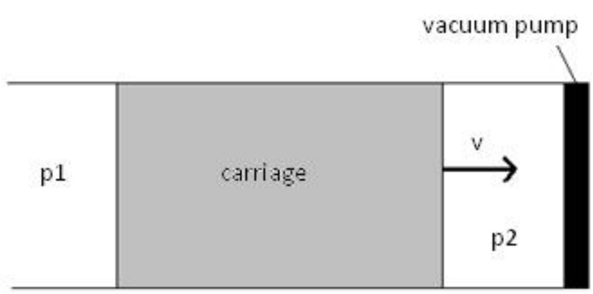

Figure 1: Left, Robida's original sketch. Right, diagram of proposed pneumatic tube train.

The pressures either side of the carriage are different, p_1 is kept at atmospheric pressure whilst p_2 is decreased using the vacuum pump. The difference in pressures drives the carriage forwards. Considering the forces involved, and including a force due to the friction of the carriage on its rails, it is possible to determine its acceleration,

$$\sum \boldsymbol{F} = p_1 A - p_2 A - \mu_k mg = m\boldsymbol{a}\,, \qquad (1)$$

where p_1 and p_2 are the pressures to the left and right of the carriage respectively, A is the carriage's cross-sectional area, μ_k is the coefficient of kinetic friction, m the carriage's mass and g the acceleration due to gravity.

It is important that the tube train adheres to certain safety regulations with regards to the acceleration involved. According to a study into safe g forces for roller coasters, the maximum g force recommended is $2g$ [3], therefore a reasonable ideal acceleration for the tube train would be $1g$ or 9.81ms^{-2}. Given that a person should be able to comfortably stand within the carriage, the internal diameter should be at least 2m; including a wall thickness of 15cm this gives a cross sectional area of 4.15m^2. Rearranging (1) and substituting for an ideal mass of 2500kg (as specified by Robida's model), an appropriate value for p_2 can be found:

$$p_2 = p_1 - \frac{(ma + \mu_k mg)}{A} = 91870Pa, \quad (2)$$

assuming a coefficient of kinetic friction for steel on steel of 0.6 [4].

However, it would be more convenient if the train could operate between a range of safe accelerations dependent upon the mass of the carriage and passengers. For acceptable accelerations of between $0.5g$ and $2g$, the mass range would be 1538kg-3636kg.

Given a distance of 1km over which to accelerate, this train system could reach high speeds given by

$$v = \sqrt{2as} \quad (3)$$

where v is the velocity after acceleration from 0 ms^{-1} over a distance s. This equates to 504.3km/h for the ideal mass, ranging from 356.6km/h to 713.1km/h for the mass range previously specified. For comparison the record speed of the TGV Atlantique is 515km/h [5]. The speed of the pneumatic tube train could be easily controlled by adjusting the vacuum pressure; compressed air injected from the vacuum side would provide deceleration.

Conclusion

An idea for a new form of public transport based upon an early science fiction novel has been presented. The pressures required for its operation are attainable at 0.907 atmospheres, allowing it to reach high speeds given a suitable distance. As an alternative to other forms of public transport, this idea shows potential and this article does not find any problems with the initial concept.

References

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