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EFFECT OF FRICTIONAL TRACTION AT CONTACT AREA FOR TRAIN BRAKING DISTANCE

تأثير أحتكاك السحب عند مساحة التلامس على مسافة ايقاف القطار

By

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الخلاصة :

تم فى هذا البحث فحص مسافة الايقاف ومعامل الاحتكاك تحت ظروف متغيرة بين العجلة والقضيب مثل وجود التراب ، الزيت ، الرمل والزيت معا على القضيب ، وقد وجد أنه نتيجة لتسيير القطارات للظروف البيئية تتغير حالة القضيب من الحالة الجافة النظيفة الى أحد الظروف السابقة ، وبناء عليه فان مسافة الايقاف تتغير . لذا يجب معرفة مسافة الايقاف الصحيحة عمليا وكذلك استنتاجها نظريا ، وقد وجد أن المعادلة النظرية فى صورة :

$$F_1 = -\frac{\tilde{p}}{2} - B\left(\frac{R}{h_o}\right)^{1/2} \eta \, (U_2 + U_1)$$

تكون مشابهة للتجارب العملية لاستنتاج مسافة الايقاف الصحيحة وذلك للحالة اللزجة فقط . كذلك أمكن ايجاد معامل احتكاك جديد $\bar{c}\bar{f}$ ليستخدم بنجاح فى المعادلة الخاصة بمسافة الايقاف للحالات الأخرى .

SUMMARY - In this investigation the braking distances and friction traction loss factor has been examined, under different conditions between the wheel and the rail (i.e Dust, oil and oil + sand on railway)

Running or environmental conditions change the state of dry clean railway to previous conditions, inturn the braking distance also changes. The exact right braking distances must be known experimentally and hence deduced theoretically.

An equation in the form of

$$F_1 = -\frac{\tilde{p}}{2} - B\left(\frac{R}{h_o}\right)^{1/2} \eta \, (U_2 + U_1)$$

For viscous condition was found suitable to fit well the results obtained for the prediction of braking distance. A new friction traction loss factor ($\bar{c}\bar{f}$) was found and used successfully in the equation of braking distance.

1. INTRODUCTION

The purpose of the present work is to determine the effect of friction traction lossfactor of train wheel and railway on braking distance. The locomative during it's movement at various speeds and environmental conditions may be exposed to conditions of sudden stoppage. Stoppage should be as planned i-e in a certain known distance, this is for the sake of safety and service, other wise the train by it huge mass may be exposed to damage

In railway stations, and in some railway regions, the engine oil falls on the rail, this is due to the stopping of many trains in one main station i.e cairo railway station, also the sand and the dust comes on the rail, due the environmental conditions

References [1, 2, 3,] to study this phenomena but now has been made under the environmental conditions of the Egyptian Railway system.

NOMENCLATURE.

A : Cross section area of air pressure cylinder cm^2
a : Hertz contact radius mm
a : $[1.365 \frac{RW}{E}]^{1/3}$
E : modulus of elasticity kgf/cm^2

$$\frac{1}{E} = \frac{1}{2}\left[\frac{1-\nu^2}{E_1} + \frac{1-\nu^2}{E_2}\right]$$

E_1, E_2 : modulus of elasticity, for wheel and Rail respectirely
e : coefficient of brake lever system (90 - 95%)
ef : friction traction loss factor
F_1 : F_2 : Rail and wheel friction forces respectively
F_d : Brake friction force
f : Coefficient of friction
f_s : f_k : static and kinetic coefficient of friction respectively
g : Acceleration of gravity 9.81 m/sec^2
h : film thickness between wheel and rail
h_o : Minimum film thickness

$$h_o = \left(\frac{1.95\, R^{\frac{4}{11}} (\eta_o u \alpha)^{\frac{8}{11}} E^{\frac{1}{11}}}{\bar{w}^{\frac{1}{11}}}\right)$$

N : Revolution per minute
P_b : Braking air pressure
$\dot{P}$: Normal pressure force
p : Air braking pressure
R, r : wheel and brake radius respectively
S_b : Braking distance
t : Braking time in sec.
U_1, U_2 : Rail and wheel speeds respectively
U : $(U_1 + U_2) / 2$
W : Load kgf.
$\bar{W}$: Load / cm of width
θ_1 : $\pi / 2$ = inlet angle
θ_2 : $\pi / 2$ outlet angle
Z : viscosity N. sec / m^2
α : Pressure component of viscosity cm^2 / kgf
ν : poison's ratio

2. EXPERIMENTAL WORK

The experiments were carried out in Tanta-Railway Station , by locomotive maintenance workshop. The facilities available there enabled the investigation to be carried out on areal system, composed of a locomotive and railway.

2.1 Locomotive

The locomotive used is a canadian general motor, which weights 78 tons, and of 4- Axles

The wheels are made from st 37., while the brake shoe is from cast iron. The speed of the locomotive is read from counters in cabient of the driver, also the pressure of the brake is read on counters in the same cabinet. The average speed of the locomotive reachs to 100 km/hr.

2.2 Distance of Brake

The distance of the brake is marked on the rail by fixed signals (which are the telphone post). The distance between each two post is 62.5 m.

2.3 Time of Stoppage

The time of stoppage in seconds is determined by stop watch.

2.4 Friction-Material Between Wheel and Railway

Three types of friction materials were used namely, locomtive oil lubricaut, sand and dust, and added by equal percentages.

These material were used seperately or together (or oil + sand). The friction material is sprayed on the rail

2.5 Brake and Air Pressure

Air working pressure is between 3-3.7 kgf / cm^2. The locomative is equipped by automatic compressed air shoe brake. This system requires a pipe running from air compressor to drivers brake valve in cabient, and hence to the brake cylinders. The wheels brakes are applied by the train drivers brake valve. The friction material of shoe brake must be new, for every set of experimental measurments.

3. THEORITICAL

3.1 Tangential (Viscous) Forces Acting on the Wheel and Lubricated Rail

Fig. (1) Illustrates the wheel train running on a rail by driving speed U_2, and support a load w which creats a pressure distribution at contact area as shown in the figure.

If the driver applied a braking force P_b by air pressure, this force creats braking friction force F_d and normal pressure force $\bar{P}$ on shoe brake inturn friction forces F_1, F_2 on the rail and the wheel respectively.

It is assumed that the contact between the wheel and the rail as elasto-hydrodynamic lubrication.

The friction force is determined from the following equation given in references [4, 5, 6, 7, 8]

$$F_1 = \int_{\theta_1}^{\pi/2} \left[\frac{h}{2R} \frac{dp}{d\theta} - \frac{\eta}{h} (U_1 - U_2) \right] R \, . \, d\theta \qquad (1)$$

at $\theta > \theta_2$ cavitation boundary

where

$$P = 0.0 \text{ and } \frac{dp}{d\theta} = 0.0$$

$$F_1 = (hp)_{\theta_1}^{\theta_2} - \int_{\theta_1}^{\theta_2} p \frac{dh}{d\theta} \, d\theta - \eta \int_{\theta}^{\pi/2} \frac{U_1 - U_2}{h} R \, d\theta$$

The first term in the equation is zero, since the pressure is zero at the two boundary condition's. The boundary conditions assumed are as follows :-

Pressure generation at $\theta = -\frac{\pi}{2}$

Pressure generation terminates in the divergent film where $p = o$ and $d\,p \,/\, dx = o$.

The second term represent the resultant pressure force $\bar{P}$ on the wheel in X direction. The last term requires integration. The values of forces are given by :-

$$F_1 = - \left[\frac{\bar{P}}{2} + B \left(\frac{R}{h_o} \right)^{1/2} \eta \, (U_2 + U_1) \right] \qquad (2)$$

$$F_2 = - \frac{\bar{P}}{2} + B \left(\frac{R}{h_o} \right)^{1/2} \eta \, (U_2 + U_1) \qquad (3)$$

$$\bar{P} = (U_2 + U_1) \, 4.58 \left(\frac{R}{h_o} \right)^{1/2} \qquad (4)$$

$$W = (U_2 + U_1) \, 2.45 \left(\frac{R}{h_o} \right)^{1/2} \qquad (5)$$

Purday's analysis (9) gives a value of $B = 3.48$ for cases where $\frac{R}{h_o}$ is large (e.g $10^2 < \frac{R}{h_o} < 10^8$).

From Figure (1) the friction torque equation is aiven by :-

$$F_1 \, R = W \, a \qquad (6)$$

3.2 Braking Distance Equation

The workdone is determined from the equation.

$$F_1 \times S_b = F_d \, . \, r \, \frac{\pi N}{60} \, . \, t = \frac{W \, (U_2^2 - U_1^2)}{2g} \qquad (7)$$

The equation enables the calculation in terms of the mass and speed of the train.

From Fig 1:-

$$F_1 = F_d \cdot \frac{r}{R} \quad \text{i}$$

$$F_d = ef \cdot P_b \quad \text{ii}$$

$$P_b = p \cdot A \quad \text{iii}$$

Friction traction loss factor (ef) can be calculated from equations ii, iii, i 4 and 2 or 6.

By combining equations 7 , i , ii and iii the braking distance equation can be written as :-

$$S_b = \left(\frac{1}{ef}\right) \cdot \left[\frac{R}{r} \frac{1}{A}\right] \frac{W\,(U_2^2 - U_1^2)}{2g\,p} \qquad (8)$$

precise analysis of equ. 7 would therefore compute the mean distances in series of time stages based on the number of brakes actually applied.

It must be accepted that there are "ef" factors in eq. 8 which are difficult to determine with high degree of accuracy, to control the exact distance. Hence the experimental part is very important to compute the friction traction loss factors ef.

4 RESULTS AND DISCUSSION OF RESULTS

Experimental and theoretical analysis of train braking distance and friction traction loss factor "ef", has been carried out to obtain safe braking distance for known friction traction loss factor.

Experimental data are plotted in Fig. (2) between the braking distance and train speed in addition to the theoretical results of oily Rail using equation's 2, 4, 7.

It is evident from the curves that the variation of braking distance between 0-300 metre, is high for oily + sandy rail while the variation is small for curves representing dusty and oily rail.

Over 52 km/hr train speed for oil curve and 60 km/hr for dust curve the rate of increasing braking distance is large and becomes larger at 90 km/hr.

The braking distance at 100 km/hr is about 2400 metre for sand-oil curve. Accordingly, at this case, care should be taken withrespect to presumed braking distance when the speed is 100 km/hr.

Fig. (2) also shows a comparison between measured and calculated braking distance using equations 2, 4 and 7 for oily rail condition only. There are similarities between the experimental values of braking distance and those calculated theoretically.

For oily rail condition, the theoretical equation of braking distance fits well the experimental results and up to a speed of 70 km/hr, and above that the equation should be rearranged to suit the experimental.

Friction traction loss factor, experimental results for three different rail conditions are shown in Fig. (3). This figure shows that with increasing sliding speed the friction traction loss factor decreases. The main feature of this figure is that the friction traction loss factor of sand + oil curve has a small values than the values of other conditions. Hence, the braking distances are very long. Fig. (4) shows theoretical results of equ. 8 The trends of the three curves are the same of experimental curves Fig. 2.

It is evident that the theoretical braking distance is very high, this is due to that the friction traction loss factor is small hence anew friction traction loss factor ef, has been deduced from the experimental and theoretical results. This new friction traction loss factor $\bar{e}\bar{f}$ is plotted against train speed in Fig. (5), this is to find the real braking, distance.

By using the friction loss factor $\bar{e}\bar{f}$ the exact braking distance can be calculated theoretically from equ. 8 Similar to that measured experimentally as in Fig.2.

It is evident from these curves in Fig. 5 that the friction traction loss factor $\bar{e}\bar{f}$ tends to decrease in the three cases at speed a bove 50 km/hr in average. i.e. irrespective of the conditions in the contact region between the wheel and the rail.

5. CONCLUSION

1- The braking distance increases with the increase of train speed, irrespective of contact conditions in the contact region between the wheel and the rail.

2- The existance of dust on the rail, provides the heighest resistance to stoppage, reflected on the lowest braking distance compared to oily and oily + sandy conditions

3- for oily condition in the contact region there is aclose agreement between the experimental and theoretical braking distance as calculated from the derived equation up to speed of 70 km/hr.

4- The friction traction loss factor ($\bar{e}\bar{f}$) tends to decrease for speed above 50 km/hr.

5- For train driver, theoretical calculation of the exact braking distances can be known or mapped at all speeds and for different rail conditions and braking pressures.

This is by using the new correction-friction traction loss factor $\bar{e}\bar{f}$ in equ. 8.

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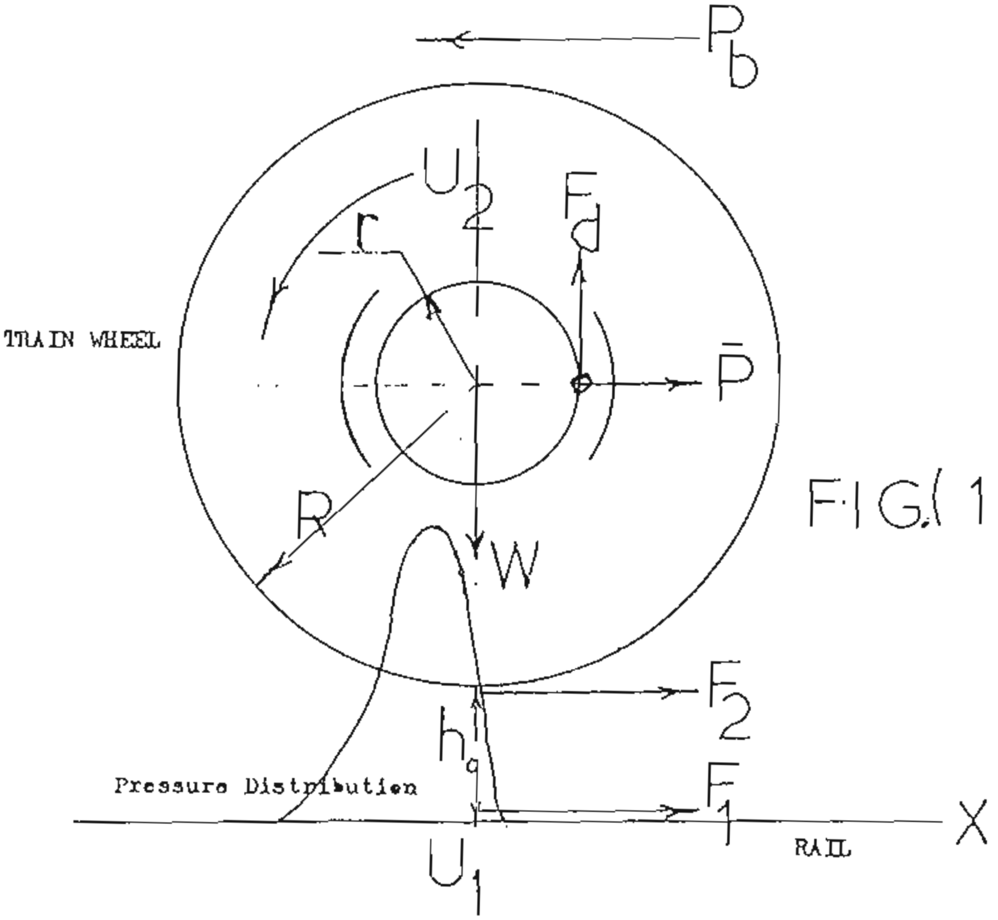
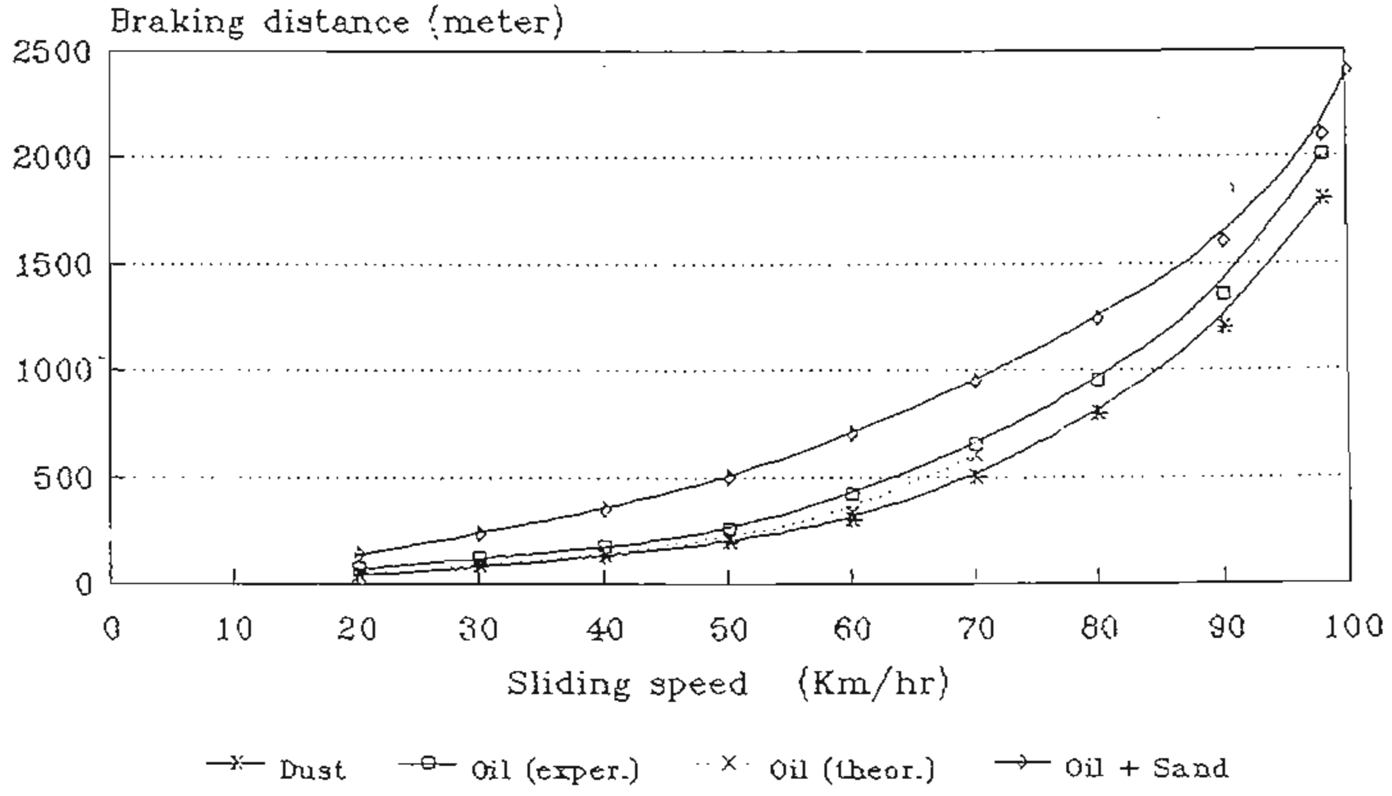


FIG.(1)

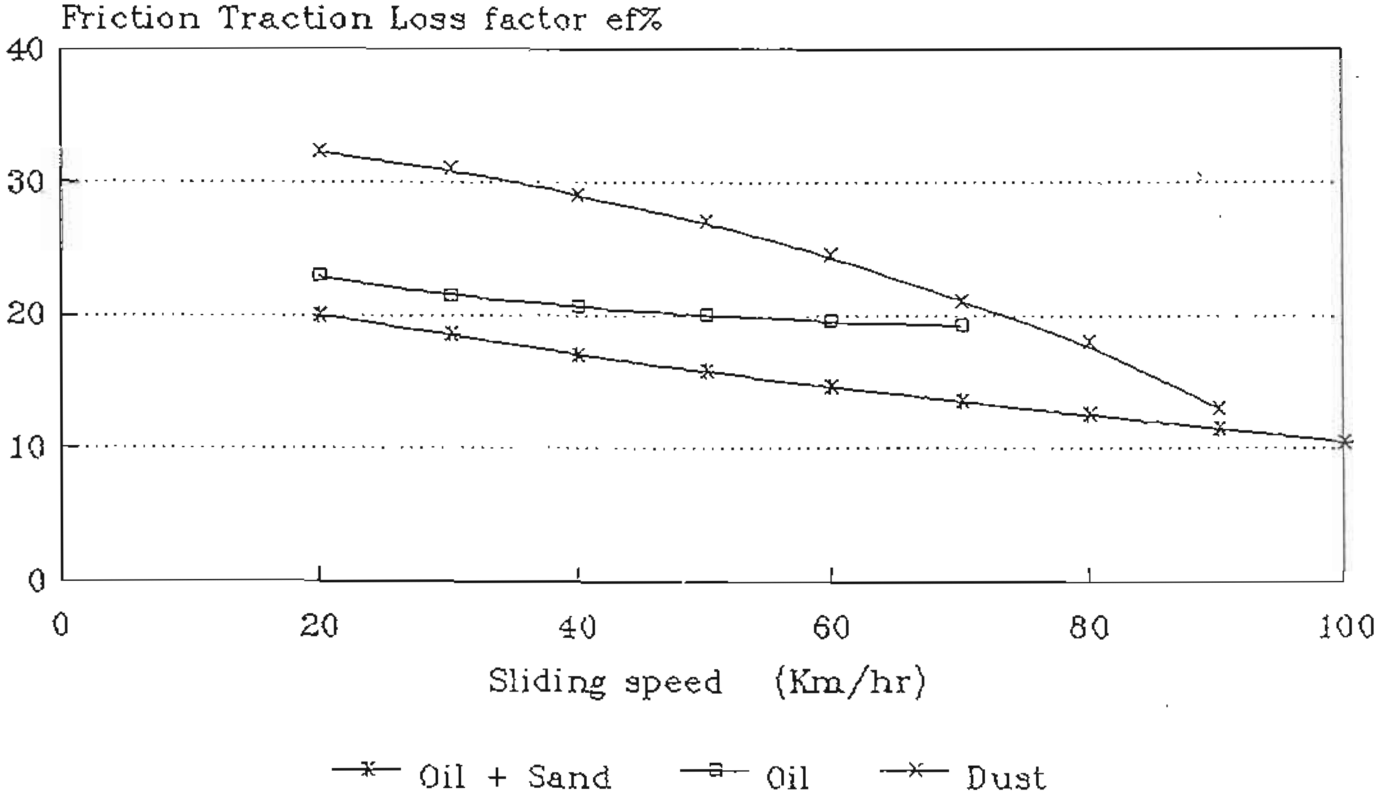
Shown in Fig. 1 the forces acting on the wheel of the train and the rail.

Fig(2): Experimental Brake distance and Train speed for different material on Railway



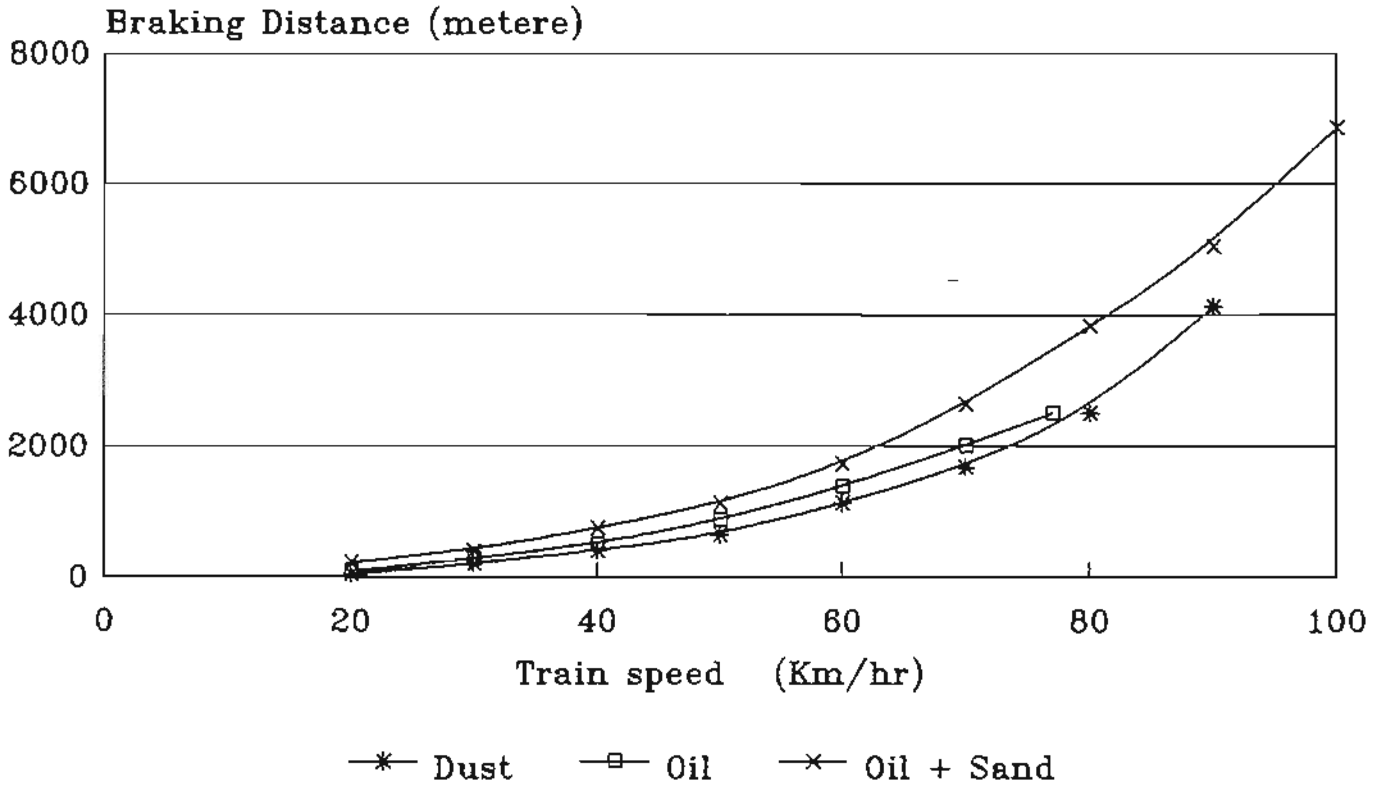
Total Load = 78 ton . Oil SAE 40
Air Brake Pressure 3.5 Kgf/cm-2

Fig(3): Experimental Friction traction loss factor ef% and train speed for different material on railway



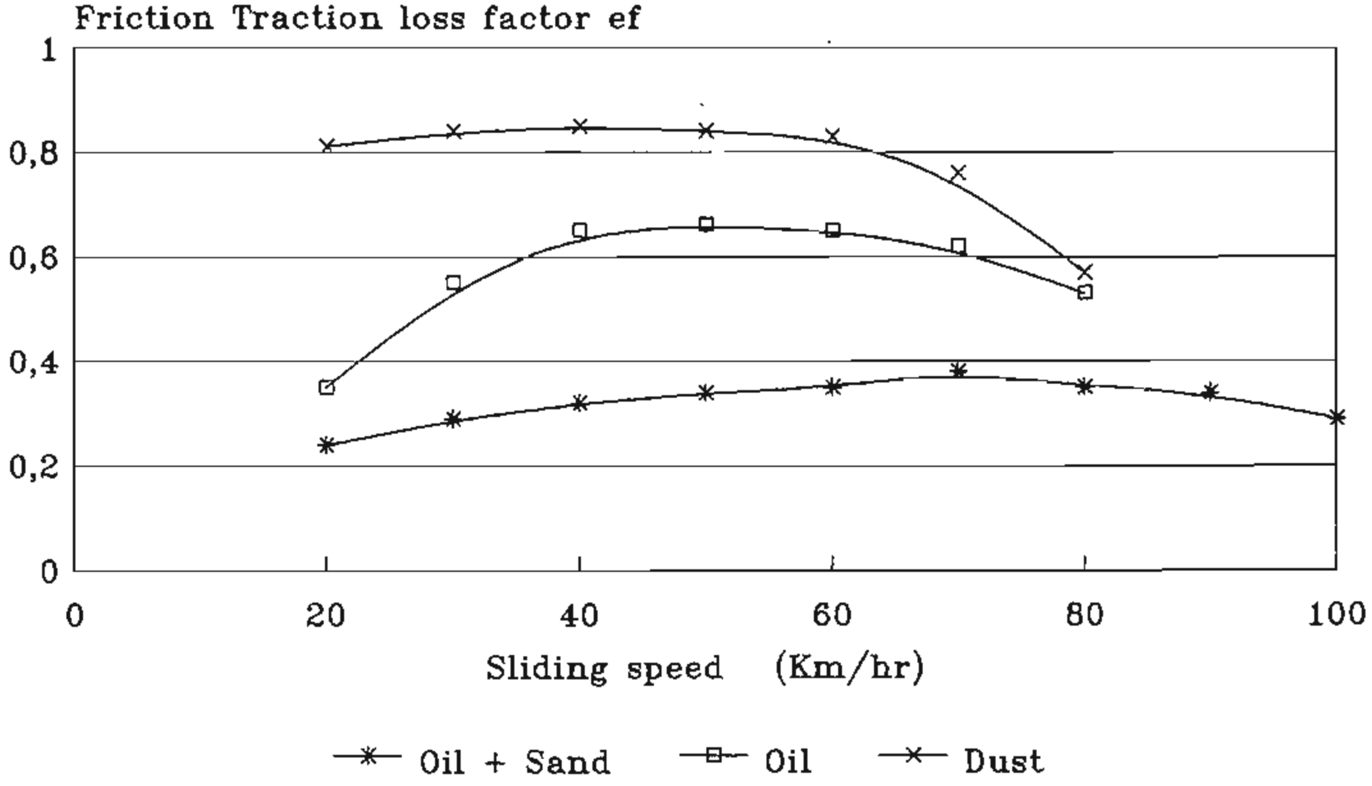
Total Load 78 ton , Oil SAE 40
Air Brake Pressure 3.5 Kgf/cm-2

Fig(4): Theoretical Braking distance and train speed for different materials on the railway (Equation 8)



Total Load 78 ton , Oil SAE 40
Air Brake Pressure 3.5 Kgf/cm~2

Fig(5): Deduction of friction traction loss factor ($\bar{e}\bar{f}$) and train speed for different materials on railway



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