Developing a Simple Computer Model for Fluid Coupling

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Abstract

Fluid coupling is regarded as an essential mechanism in semi-automatic transmission systems which are used in most new and advanced heavy vehicles . It has already replaced the ordinary mechanical coupling and clutch units . It has a great advantage of reducing torsional and transverse vibrations. In addition , changing gear ratios can be accomplished easily without difficulty .

Curve fitting technique with the aid of computer has emerged as a compelling animation technique . Yet current approaches to fluid coupling simulation are inefficient or can't handle some relevant scenarios robustly . A practical results of a certain fluid coupling has been chosen which were used in " Reem " buses and were utilized by the State Company for Automotive Industries at Iskanderia in Iraq . However , and when modeling the complete engine transmission system , these practical results were not easy to follow and apply . The aim of this work is to develop a simple and flexible model for a fluid coupling . The object is to obtain a simple relation among fluid coupling main controllable variables , so that is can be utilized easily in a future comprehensive model of engine-transmission system used for steady state and dynamic analysis .

الخلاصــــــة

يعتبر الموصل الهيدروليكي جهاز ضروري في أجهزة نقل الحركة شبه الذاتية في معظم المركبات الثقيلة والحديثة , فهو يستخدم بديلا عن الفاصل الميكانيكي والرابط الميكانيكي , أضافة الى أنه يعمل على تقليل الأهتزازات و على سهولة التبديل أثناء نقل القدرة من الماكنة الى الحمل .

تمت الأستعانة من نتائج عملية لأحدى التصاميم المتوفرة لموصل هيدروليكي يستخدم في باصات "ريم" الحديثة والتي كانت تصنع في الشركة العامة للصناعات الميكانيكية في الأسكندرية في العراق . أن النتائج العملية المتوفرة لدى الشركة غير سهلة التطبيق لبناء نموذج حاسوبي مرن سهل الأستخدام . لذا فأن هذا البحث يتضمن تطوير وأستنباط نموذج رياضي مبسط بأستخدام الحاسوب لأيجاد ثوابت

هذا النموذج الرياضي عن طريق أيجاد علاقة مبسطة تربط المتغيرات الأساسية الرئيسية مع بعضها في الموصل الهيدروليكي . أن الهدف طن هلذا البحث هو الأستفادة من هذا النموذج الرياضي مستقبلا لعطنع نطوذج شامل لأنظمة المركبات الحديثة و أطتخدامه في التحطيلات المطتقرة والديناميكية في أنظمة هذا النوع من أجهزة نقل الحركة شبه الذاتية .

1. Introduction

The fluid coupling is a form of clutch in which crankshaft torque is transmitted to the input shaft of the gearbox through the effect of centrifugal force upon a low-viscosity oil [1] . The percentage of torque transmitted by the coupling depends upon the speed of the engine . Fluid coupling has been used as the primary hydrodynamic drive unit for passenger car and heavy trucks step-gear transmissions since 1939 , and somewhat earlier as a starting device . It has been used between the engine and the conventional clutch , in 3-speed synchromesh transmission . It was utilized later as a shifting clutch in passenger car transmission starting in 1955 . The transmission was introduced in which the same hydrodynamic unit was used as both the primary drive unit and a shifting clutch . Fluid coupling can also be used in winches , cranes and turbine driven compressors .

The most common type of the fluid coupling which is shown in figure (1) is known as a "two-member drive coupling" . It consists of driving member is called the pump or impeller (primary) and the driven member is known as the turbine (secondary) . Both elements are contained in suitable housing (shell) .

The fluid coupling , in performing the combination of function , for which it is suitable , offers the advantages of complete smoothness during its speed ratio changes .

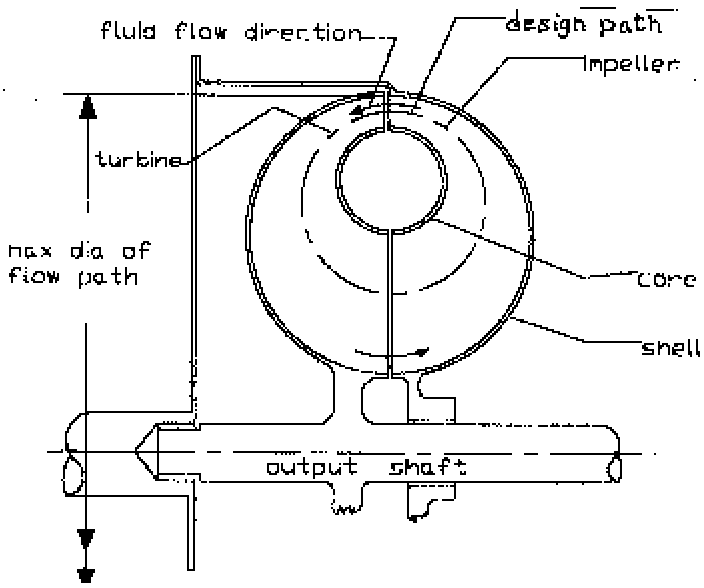

Fig. (1) Two Member Fluid Coupling

Considering the complex nature of these changes ,the unit is relatively simple and reliable . It can be designed to be sufficiently rugged and durable to last the life of the vehicle with out requiring service . When the fluid coupling is driven directly by the engine , the other drive line components are substantially free of effects of the normal engine torsion vibrations , and thus eliminating the need for dampers or isolators . Shock effects on the drive line components resulting from abrupt changes in transmissions gear ratio alteration are greatly reduced . And as a result , longer life for nearly all functional transmission components of the vehicle have been noticed reducing repair costs .

The advantages of employing a fluid coupling are , effective damping of shocks , power transmission occurs without wear . Also , matching to maximum torque which is utilized easily during the complete start up procedure . This will lead to economy-reduced maintenance due to the optimum protection of all mechanical drives elements , in spite of reasonably good efficiency .

The simulation of fluid coupling is important in understanding the dynamic behavior of the engine – transmissions system [2,3,4,5] . However , without using a simple dynamic equation , the simulation could not be achieved . The object is find this simple equation which can be utilized in the future in the simulation of fluid coupling . This will be disused especially when taking the inertia effect in a future research .

2. Related Practical Work

Recently , there has been an increasing interest in modeling vehicle engine-transmission components used in heavy vehicle and buses . The object was to optimize the overall performance and thus achieving a better overall efficiency .A specially designed a "fluid coupling" which is used by Iraqi State Company for Automotive Industries Iskanderia [6,7] , has been utilized in this work .

The basic equation for fluid coupling is as follows [8] :-

$$T = C\ D^5\ N^2 \qquad \text{……....(1)}$$

Where :-

T = fluid coupling torque (N.m) , C = capacity constant of the fluid coupling $(N.(rpm)^{-2}.m^{-4})$, D = size of flow path of the fluid coupling (m) , N = speed (rpm)

However , C is always changeable because different diameters used of design path . In addition , C varies with different temperatures and other conditions . The speed ratio "SR" (turbine or output speed / impeller or input speed) has a great influence on the value of torque This is shown in figure (2-a) where impeller speed versus impeller torque has been plotted for different values of (SR) . Also , figure (2-b) , shows a straight line curves in two-to-one slope of logarithm of impeller speed versus logarithm of impeller torque of "two members" of fluid coupling .

Example of the operating characteristics of fluid coupling are shown in figure (3) . This represents the experimental results of a particular type of fluid coupling used by the 17-ton loaded Iraqi "Reem city bus" [6] . The bus was of on early version used in urban area which is selected and to be utilized in this work . The already mentioned figure is not easy to follow since the value of engine torque should not exceed that of the engine curve . And as a result , and to model this curve is not easy , since speed ratio varies always from 0 to 100 . The aim of this paper is to find a new and a flexible method for understanding the behaviour of figure (3) .

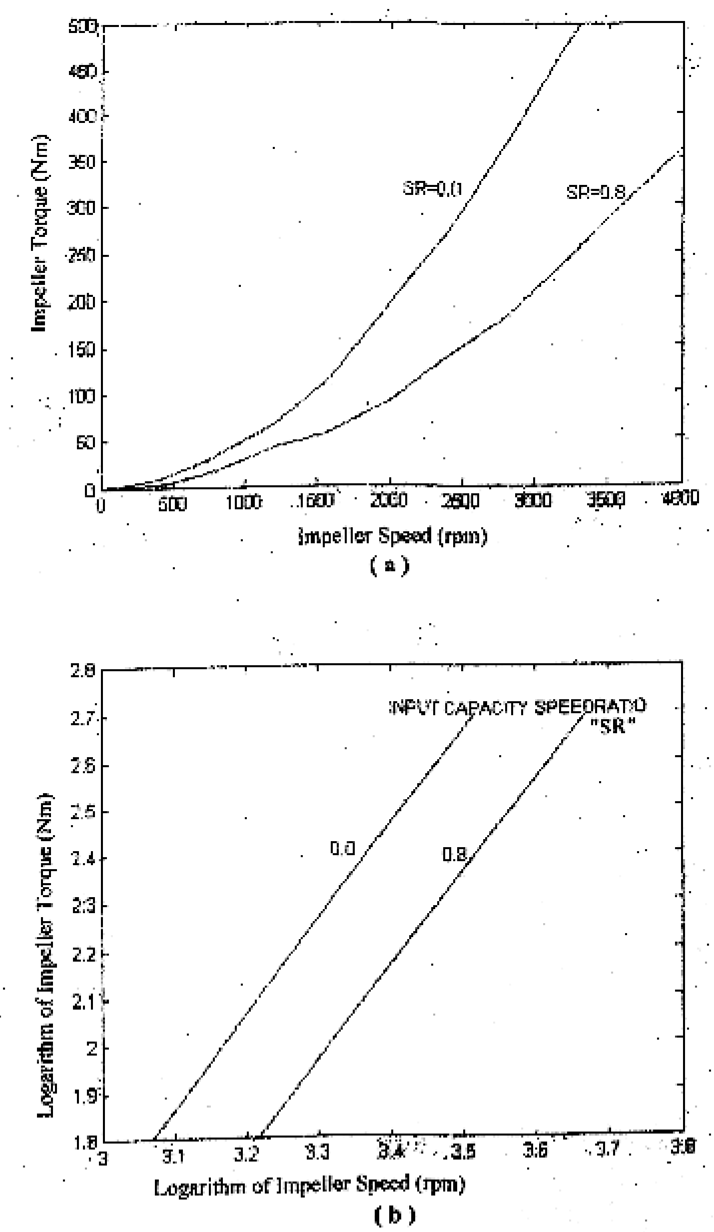

Fig. (2) Variation of Impeller Speed versus Impeller Torque of Certain Fluid Coupling Different Speed Ratio "SR" [6]

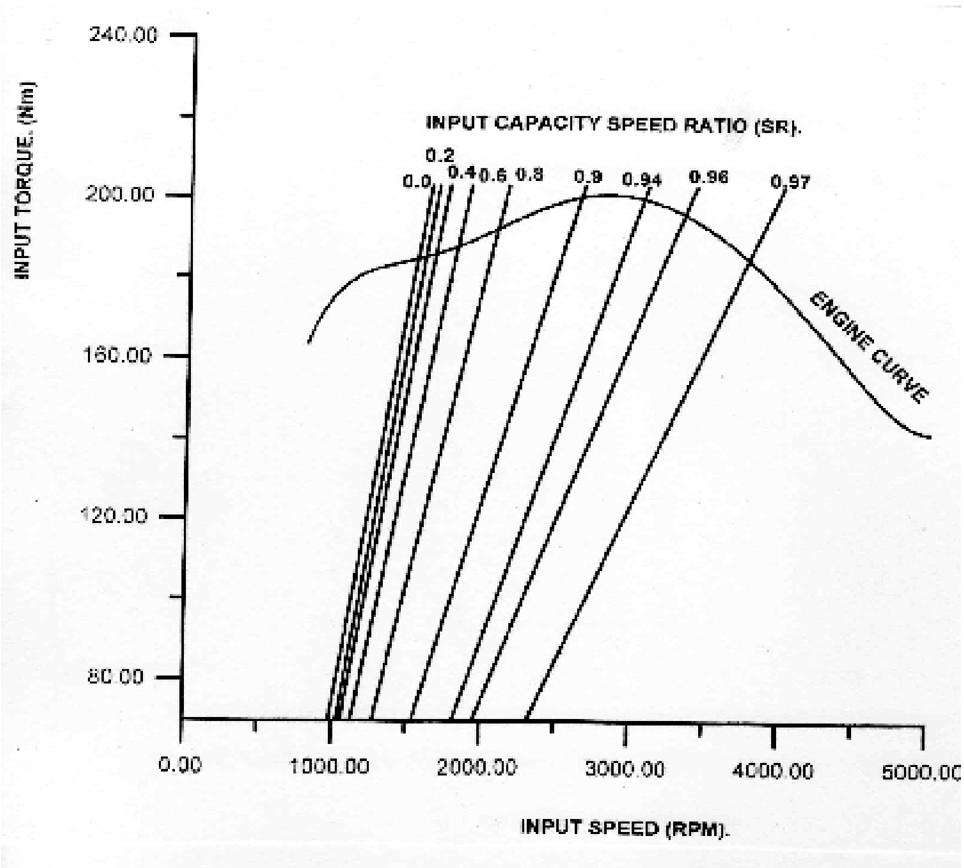

Fig. (3) Typical Input Capacity Plot to Determine Operating Conditions of Engine and Hydrodynamic Unit (Experimental Results) [6]

3. Developing a "Simple" Equation

The object is to achieve a simple relation for all 3 controllable variables used in a fluid coupling . Then a flexible model can be developed in such an easy way that can be connected dynamically with a comprehensive model -ready for use- in future analysis . The semi-automatic transmission system is often mis-used especially by bus drivers . This will lead to changing the whole transmission after a short period , which is very common in Iraq and this is problem .

Figure (3) , and usually for all similar curves of fluid coupling characteristics , it was found from practical results and for a given value of speed ratio , the ratio of the fluid coupling torque to the square of the primary element speed is almost constant [6] . This is a slightly different from equation (1) . Then , the following relationship can be written :-

$$\frac{T}{(\omega_E)^2} = f(SR) \qquad \text{.......... (2)}$$

And the object is to find this relationship . With regard to fluid coupling characteristics , seven points have been selected on this particular curve . For particular speed ratio which is equal to zero , the average values of [torque / (engine speed)^2] of these seven points have been calculated , as shown in table (1) .

Table(1) The operating conditions of engine and fluid unit for zero" SR " from fig. (3)

i	T	ω_E	T/ω_E	$[T/(\omega_E)^2] \times 10^{-5}$
1	200	1600	0.125	7.8125
2	170	1500	0.1133	7.5560
3	146	1380	0.1058	7.6664
4	126	1260	0.1000	7.9365
5	110	1200	0.0917	7.6388
6	95	1114	0.0853	7.6551
7	83	1060	0.0783	7.3869

Where:- T in (Nm) , ω_E in (rpm) , $[T/\omega_E]$ in $[Nm(rpm)^{-1}]$ and $[T/(\omega_E)^2]$ in $[Nm(rpm)^{-2}]$

From table (1) :-

$$T/(\omega_E)^2 = [\ \Sigma\ T/(\omega_E)^2\ ]/7 = [53.6522 * 10^{-5}\ ]/7 = 7.6646 * 10^{-5}$$

Similarly, for other values of speed ratio, the average value [torque/(engine speed)^2] ,and the corresponding values of torque and engine speed can be tabulated in table (2) .

Table (2) Resultant operating conditions of engine and fluid unit from figure (3) for different values of "SR"

i	T	ω_E	T/ω_E	$[T/(\omega_E)^2] \times 10^{-5}$	SR
1	132.85	1302	0.099904	7.6646	0.0
2	130.57	1338	0.09537	7.1232	0.2
3	131.14	1388	0.09445	6.805	0.4
4	131.43	1488	0.08831	5.934	0.6
5	134.29	1707	0.07868	4.6094	0.8
6	130.60	2066	0.06321	3.0601	0.9
7	130.90	2438	0.053682	2.2015	0.94
8	134.14	2718	0.04935	1.8155	0.96
9	137.30	3160	0.04345	1.3748	0.97

Depending on the last practical results [6] , and using table (2) , the values of $[T/(\omega_E)^2]$ are plotted as the ordinate and the values of speed ratio are plotted as abscissa with a new pattern and different method , as shown in figure (4) .

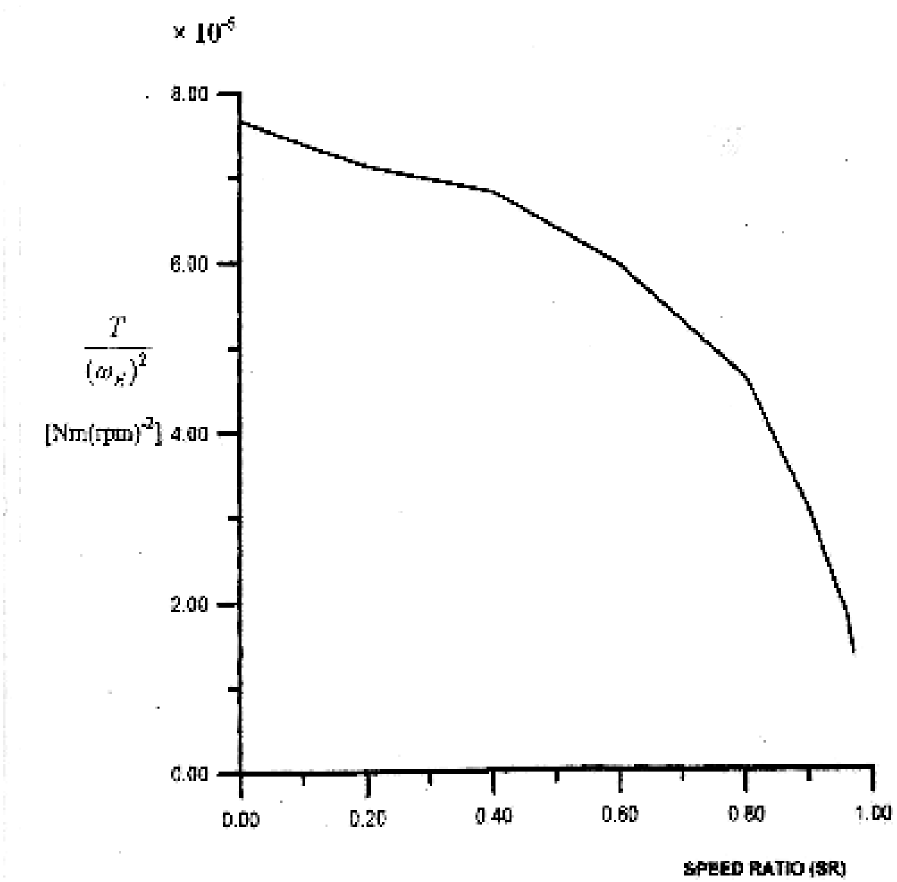

Fig (4) The New Characteristics Plot of the Concluded Practical Results Showing speed Ratio "SR" Versus [$T / (\omega_E)^2$]

Utilizing "GRAPHER , 2-D graphing system" by feeding this program the data in table (2) , the polynomial relations are obtained between the value of [torque / (engine speed)^2] with speed ratio (SR) up to 7th order , as shown is , in figure (5) . A 5th order degree relation curve can be selected , because it is the nearest curve to that of actual curve shown in figure (6) . Thus , the required equation can be written as :

$$T/(\omega_E)^2 = C_0+C_1(SR)+C_2(SR)^2+C_3(SR)^3+C_4(SR)^4+C_5(SR)^5 \quad \text{..........(3)}$$

Where :-

C_0= 7.66362 , C_1= -7.52645 , C_2= 43.8687 , C_3= -124.889 , C_4= 148.106 , C_5= -66.7866 . The units of all constants are in [Nm(rpm)$^{-2}$] , these values were obtained using the 2-D graphing computer model .

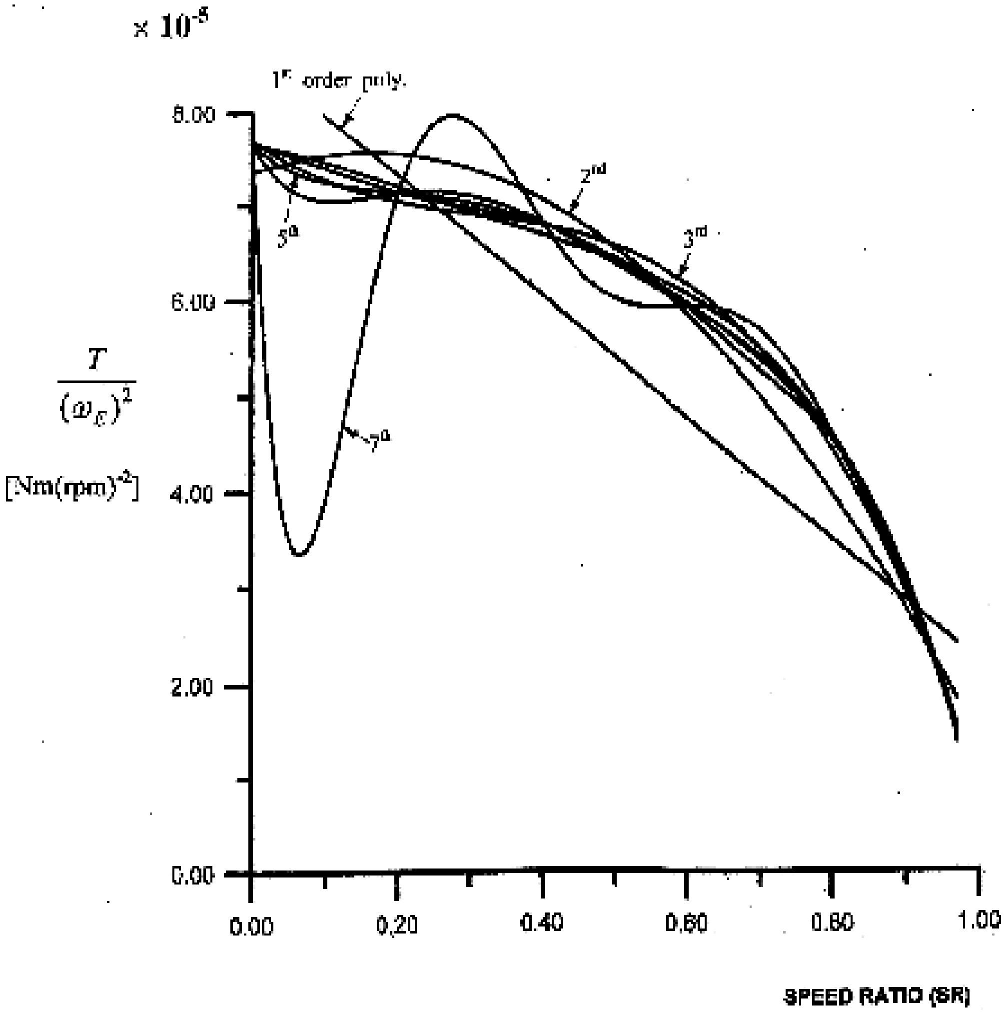

Fig. (5) Computer Plot of the Seven Types of Polynomial Relations from First Order up to Seventh Order between the Values of [T/(ωE)2] and Speed Ratio (Theoretical Results)

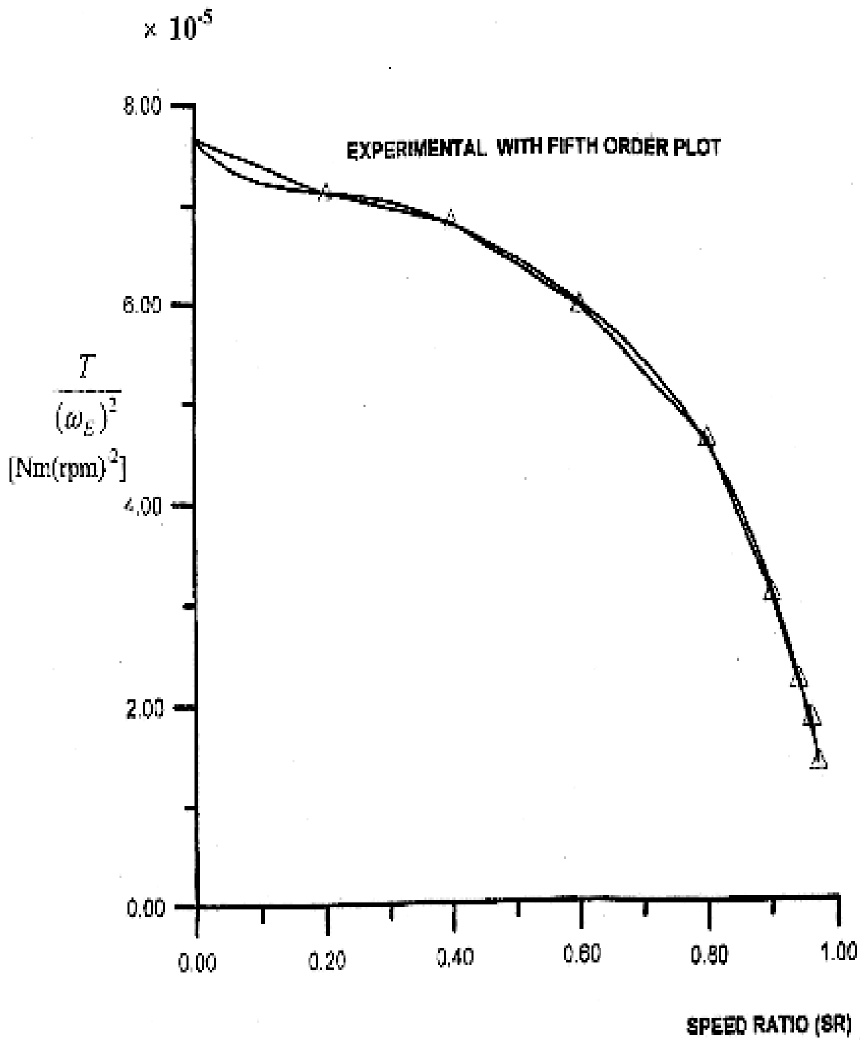

Fig. (6) The Fifth order Plot (Theoretical) with the Experimental Plot

4. Suggested Model and Concluding Remarks

It should be emphasized that one of the main objective of this work is to utilize this fluid coupling model by linking it with engine –transmission system . And as a results , a comprehensive model must be developed so that the steady state and dynamic behaviour of the whole system should be understood . Unfortunately , this will not be discussed in this work . However , the developed fluid coupling relationship (equation 3) should be incorporated as a model and a special approach could be adapted essentially for future linking procedure . Three possibilities of using this model will be discussed as follows :-

i. The input variables will be the primary speed and fluid coupling torque . The speed of the element will represent the output as shown in fig.(7 i) .

ii. The input variables will be the secondary element speed and the fluid coupling torque . . The speed of the primary element will represent the output as shown in fig. (7 ii) .

iii. The input variables will be the speeds of both primary and secondary elements while the fluid coupling torque will represent the output as shown in fig. (7 iii) .

It would be possible by applying this technique is to link fluid coupling with other engine-transmission component in a flexible method . Noting that equation (3) representing the behavior of the fluid coupling remains unchanged . It should be mentioned that without this simple equation , the above three possibilities could never been achieved easily in the modeling procedure .

Moreover , allowances could be made to include the possibility of a torque being exerted by the load on the engine . This is the case where engine is transmitting a negative torque through the fluid coupling . This occurs when the secondary element acts as a pump while the primary impeller responds as a turbine . This can actually occur for times which however short are not negligible . The model , and because of its simplicity , can include this reality and which is important when dealing with transient analysis of the whole system , and it is hoped that this will be shown in a future work .

Notations

Symbol	Meaning	Unit
T	fluid coupling torque	N.m
C	capacity constant of the fluid coupling	N.(rpm)$^{-2}$ .m^{-4}
N	speed	rpm
D	size of flow path of fluid coupling	m
C_O ,C_1 , ... ,C_5	constant	Nm.[rpm]$^{-2}$
SR	speed ratio (ω_E / ω_S)	---
ω_E	engine speed or primary speed	rpm
ω_S	speed of secondary	rpm

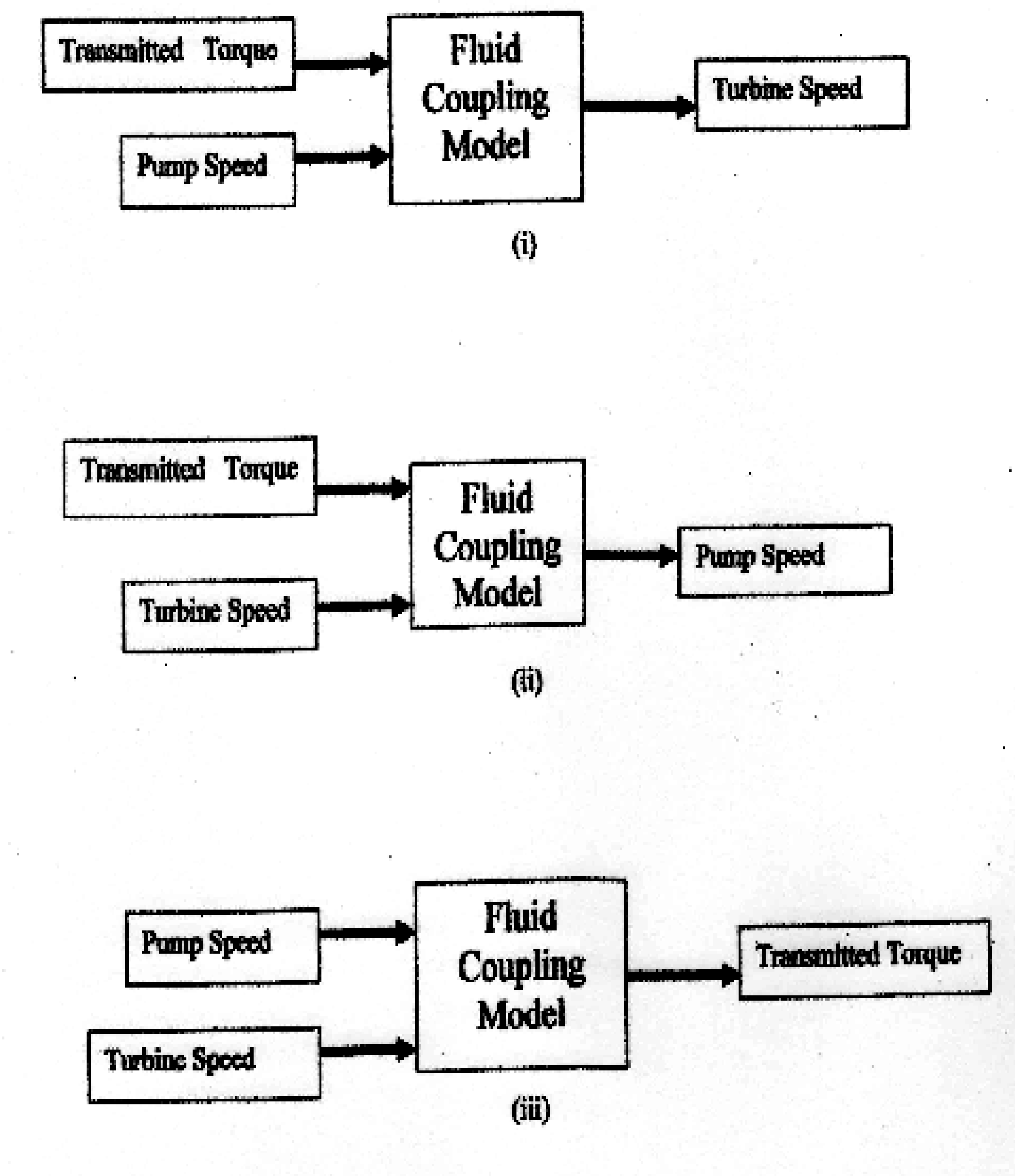

Fig. (7) Simplified Block Diagrams Illustrating the Three Possibilities used in . Fluid Coupling Model

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