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Investigate of Movement of the Cannonball in the Gas Along with the Friction Force

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Abstract

We consider a ball moving in the xy-plane spinning about an axis perpendicular to the plane on the motion. The typical trajectory of the ball is shown in figure 1.

Keywords: cannonball, friction Force, aerodynamics, dynamics

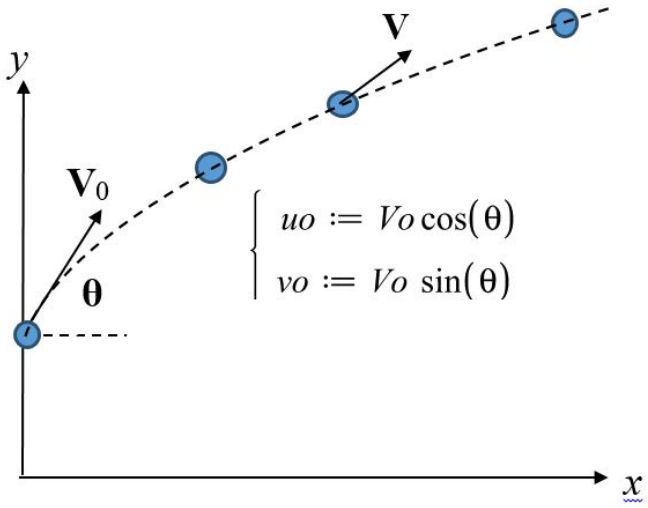

Figure 1: Throw a bullet from a height

Mathematical formulation of the problem

The force acting on the ball are the Drag force, (F_D), the lift force, (F_L), and the gravitational force, (F_W) as follows:

$$F_D = \frac{1}{2} C_D A V^2 \quad ; \quad F_L = \frac{1}{2} C_L A V^2 \quad ; \quad F_w = mg \tag{1}$$

The equation of motion takes the form:

$$m a_x = -F_D \cos\theta - F_L \sin\theta \quad ; \quad m a_y = -mg - F_D \sin\theta + F_L \cos\theta \tag{2}$$

After substituting Eqs.(1) in to Eqs.(2),we have as follows:

$$\begin{aligned} \frac{dVx}{dt} &= -\frac{\rho A}{2m}\left(C_D \cos\theta + C_L \sin\theta\right)\sqrt{Vx^2 + Vy^2} \\ \frac{dVy}{dt} &= -g - \frac{\rho A}{2m}\left(C_D \sin\theta - C_L \cos\theta\right)\sqrt{Vx^2 + Vy^2} \end{aligned} \tag{3}$$

We can write:

$$\cos\theta = \frac{Vx}{V} \quad ; \quad \sin\theta = \frac{Vy}{V} \quad ; \quad V^2 = Vx^2 + Vy^2 \tag{4}$$

So, the equations can be written entirely as a system set of nonlinear differential equations for the velocity as follows:

$$\begin{aligned} \frac{dVx}{dt} &= -\alpha\left(C_D Vx + C_L Vy\right)\sqrt{Vx^2 + Vy^2} \\ \frac{dVy}{dt} &= -g - \alpha\left(C_D Vy - C_L Vx\right)\sqrt{Vx^2 + Vy^2} \end{aligned} \tag{5}$$

And value α is $\alpha = \frac{\rho A}{2m}$, where $\alpha = 0.0530\, m^{-1}$.

Initial conditions as:

$$Vx(0) = uo \quad , \quad Vy(0) = vo \tag{6}$$

By selecting the physical values at below:

$$\begin{aligned} &\alpha := 0.053;\ Cl := 0.125\left(\frac{kg}{m^2}\right);\ g := 9.81\left(\frac{m}{sec}\right) \\ &Cd := 0.05\left(\frac{kg}{m^3}\right);\ Vo := 55;\ \theta := \frac{\pi}{7}(rad) \end{aligned} \tag{7}$$

AYM solution process (Akbari Yasna's Method) Output of the solution process by new approach **AYM (Akbari Yasna's Method)** for set of nonlinear differential equation Eqs. (5), according to the initial conditions Eqs.(6) and physical values Eq.(7), the solution set of the non- differential equation is obtained as follows:

$$\begin{aligned} Vx(t) := {} & 49.55328773 - 15.91769300\, t + 2.067287320\, t^2 \\ & + 0.3624701531\, t^3 - 0.1857797791\, t^4 + 0.03755044072\, t^5 \end{aligned} \tag{8}$$

$$\begin{aligned} Vy(t) := {} & 23.86360566 + 4.76785870\, t - 4.873907394\, t^2 \\ & + 1.049483078\, t^3 - 0.1157951980\, t^4 - 0.003170631157\, t^5 \end{aligned} \tag{9}$$

Comparing the achieved solutions by Numerical Method order Runge-Kutta and AYM (Akbari Yasna's Method)

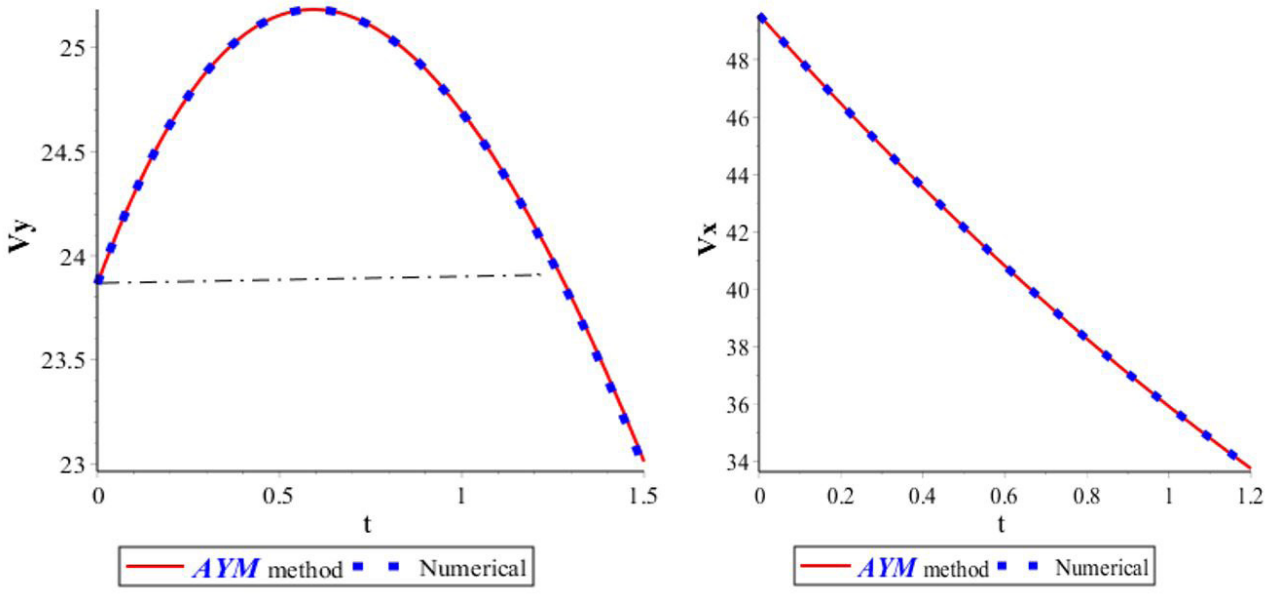

Figure 2: A comparison between AYM and Numerical solution

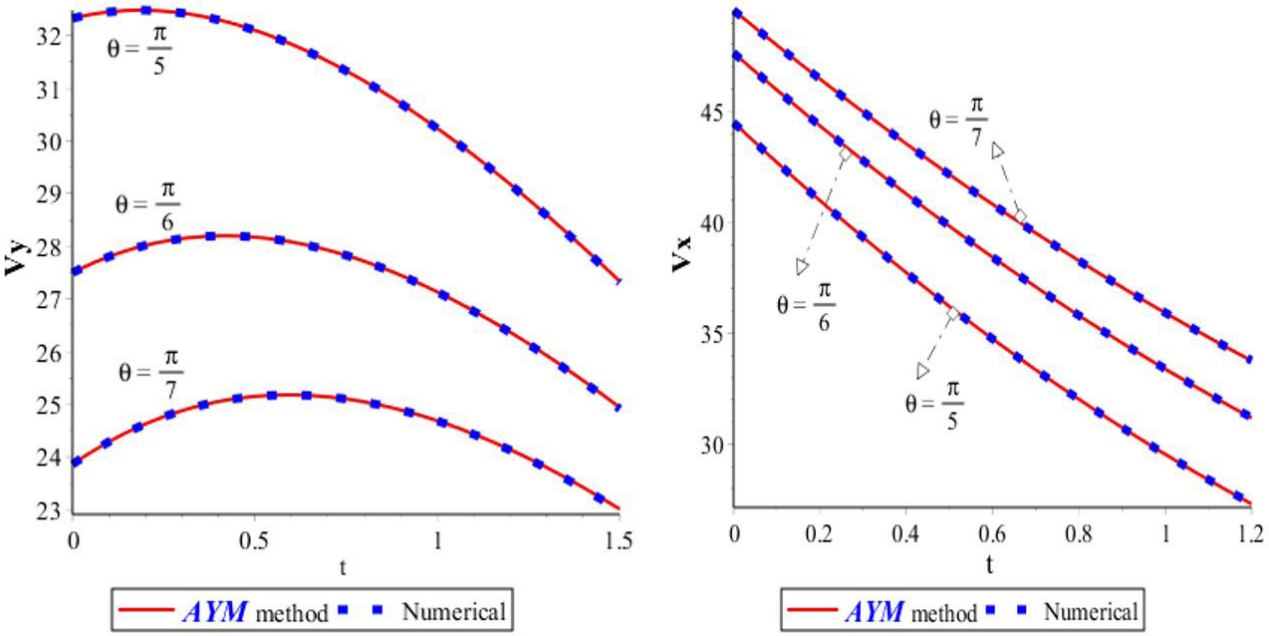

Figure 3: A comparison between AYM and Numerical solution

Conclusions

In this article, we proved that with this new method, all kinds of complex practical problems related to nonlinear differential equations in the design for motion of a solid in a fluid can be easily solved analytically. Obviously, most of the phenomena in dynamics and aerodynamics are nonlinear, so it is quite difficult to study and analyze nonlinear mathematical equations in this area, also we wanted to demonstrate the strength, capability and flexibility of the new **AYM** method(Akbari-Yasna Method).This method is newly created and it can have high power in analytical solution of all kinds of industrial and practical problems in engineering fields and basic sciences for complex nonlinear differential equations.

Acknowledgment, History of AGM , ASM , AYM , AKLM , MR.AM and IAM methods: **AGM** (Akbari-Ganji Methods), **ASM** (Akbari-Sara's Method) , **AYM** (Akbari-Yasna's Method) **AKLM** (Akbari Kalantari Leila Method), **MR.AM** (MohammadReza Akbari Method)and **IAM** (Integral Akbari Methods), have been invented mainly by Mohammadreza Akbari (M.R.Akbari) in order to provide a good service for researchers who are a pioneer in the field of nonlinear differential equations.

*__AGM__ method Akbari Ganji method has been invented mainly by Mohammadreza Akbari in 2014. Noting that Prof. Davood Domairy Ganji co-operated in this project. *__ASM__ method (Akbari Sara's Method) has been created by Mohammadreza Akbari on 22 of August, in 2019. *__AYM__ method (Akbari Yasna's Method) has been created by Mohammadreza Akbari on 12 of April, in 2020. *__AKLM__ method (Akbari Kalantari Leila Method)has been created by Mohammadreza Akbari on 22 of August, in 2020. *__MR.AM__ method (MohammadReza Akbari Method)has been created by Mohammadreza Akbari on 10 of November, in 2020. *__IAM__ method (Integral Akbari Method)has been created by Mohammadreza Akbari on 5 of February, in 2021.

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