Mathematics of Karate Techniques Dynamics & kinematics of karate

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Abstract- In this paper it is shown the interpretation of karate (attacks, blocks, stances) through kinematics, dynamics and few mathematical concepts involved and evolved. The main objective of this paper is to give mathematical reasoning, explanation and definitions to the techniques and of the karate movements & justifies the supreme and uniqueness from all the martial arts.

Keywords:Martial arts, Karate, Origin, Kinematics, Dynamics, Energy (Joules), Power, Properties, Stance, equations .

I. INTRODUCTION

Martial arts are codified systems and traditions of combat practices, which are practiced for a variety of reasons: self-defense, competition, physical health and fitness, entertainment, as well as mental, physical, and spiritual development.Although the term martial art has become heavily associated with the fighting arts of eastern Asia, it was originally used in regard to the combat systems of Europe as early as the 1550s. The term is ultimately derived from Latin, and means "arts of Mars," where Mars is the Roman god of war.

II. KARATE

The origins of karate can be traced back to ancient times and the systems of self-defense & fighting designed by Oriental priests and Asian warriors. Derived from those systems, karate, meaning "empty hand," was developed in Okinawa in the early 17th century (modern karate) after the Japanese conquered the island and banned the use of all weapons. Today, millions of people are practicing karate all over the world.

"The ultimate aim of karate lies neither in victory nor defeat, but in the perfection of the character of participants"
— Gichin Funakoshi

Gichin Funakoshi regarded as the father of modern karate. He changed the concept which meant to the tang dynasty and substituted another ideogram pronounced "Kara" meaning "empty". He derives the philosophy "rendering oneself". In 1935 Funakoshi discarded the suffix in the favor of "Do"meaning "way' and karate-do was born.
Assumptions

Let us assume the karateka weighs about 70kgs (mass) and with reference to a comparative experimental study for the speeds of different techniques. The following table which summarizes the values for the velocity

Fig 1 gichin-funakoshi (father of modern karate)

Table 1

S. NO	Velocity (speed of the technique)		
	Techniques	*Max.speed*	*Avg speed*
1	Front forward punch (middle)	$5.7 - 9.8$ m/s	7.5 m/s
2	Downward hammer fist block	$10 - 14$ m/s	12 m/s
3	Roundhouse kick	$9.5 - 14$ m/s	12 m/s

III. ENERGY PRODUCED BY KARATE TECHNIQUES

Here by applying few simple mathematics and mechanics formulae to analyze the dynamics of karate techniques to determine the energy exerted and to draw several conclusions on the efficiency of various techniques.
The following movements are to be analyzed
1.   MIDDLE PUNCH
2.   MIDDLE OUTWARD BLOCK
3.   FACE KICK
4.   A KARATE STANCE

IV.MIDDLE PUNCH

When performing a middle punch (shoden-zuki), the goal of the karate practitioner (karateka) is to keep the body in balance and achieve maximum energy when the knuckles hit the target. The hand travels a straight distance and rotates by approximately 180 degrees.

Fig (2) middle punch by right hander

The power (energy) exerted by the middle punch can be given by E

$$E = E_P + E_K + E_R$$

Where,

E$_P$ = Potential energy
E$_K$ = Kinetic energy
E$_R$ = Rotational energy

Hence

$$E = mgh + \frac{1}{2}mv^2 + \frac{1}{2}mr^2\omega^2$$

Potential Energy
m = 70 kg
g = 9.8 m/s^2
h = height of the drop (from shoulder to impact)
Assume h = 20 cm (approx.) = 0.2 m
Therefore, mgh = (70) (9.8) (0.2) = 137.2 joules
Kinetic Energy
m = 7 kg (arm weight alone)
v = 7.5m/s (from table 1)

Therefore,

$\frac{1}{2}mv^2$ = (0.5) (7) (7.5)^2 = 196.88 joules

Rotational Energy
m = 7 kg (arm weight alone)
Let us assume the radius of the forearm be 3 cm taken as a cylinder = 0.03 cm
The Fist & forearm makes a rotation of about 180^0
= 5π rad/s $\frac{1}{2}m(r\omega)^2$
= (0.5) (7) (0.03*5π)^2 = 0.788 joules

Hence the total energy by the punch is
= 137.2 + 196.88 + 0.788
= 334.868 joules………………….. (1)

Potential Energy in the Punch = 40.97%
Kinetic Energy in the Punch = 58.79 %
Angular Momentum = 0.23 %

Note:
Even though the rotational energy doesn't have a big part of impact but it has the key role in the point of impact (targeting).Only the 2 knuckles are concentrated as the point of impact.

V. MIDDLE OUTWARD BLOCK

When performing a middle block (shoden-uchi-uke), the goal of the karate practitioner (karateka) is to keep the body protected or prevented from the attack.This block is mainly used to tackle middle punch. The only objective of the movement is to divert the punch outside the body with a greater impact on the opponent forearms

Fig (3) the practice performs a block (middle)

Potential Energy
m = 70 kg
g = 9.8 m/s^2
h = height of the drop (from outward to inward)
Assume h = 33 cm (approx.) = 0.33 m
Therefore, mgh = (70) (9.8) (0.33) = 226.38 joules
Kinetic Energy
m = 3.57 kg (forearm weight alone)
v = 12m/s (from table 1)

Therefore,

$\frac{1}{2}mv^2$ = (0.5) (3.57) (12)^2 = 257.04 joules

Hence the total energy by the punch is
= 226.38 + 257.04
= 483.42 joules………………….. (2)

There is no rotational energy in this this technique so it is not considered.
From the above result it is evident that the energy exerted is greater than the energy of the punch
Comparing (1) and (2)
(i.e.) 148.552 joules greater than middle punch (44.36 %)

FACE KICK
When performing a upper face kick (jodan-mawashi-giri), the goal of the karate practitioner (karateka) is to keep the body in balance and achieve maximum energy through the rotation with the reverse leg (a small shift of angle)

But the rotation is neglected since it rises to many complications in the calculations. Only the leg which transits the energy to the shin or ankle of to hit the target such as skull or cheeks or side face is considered.

Fig 4 a karateka performing a face kick

Kinetic Energy
m = 11.9142 kg (weight attacking leg alone)
v = 12m/s (from table 1)

Therefore,

$\frac{1}{2}mv^2$ = (0.5) (1) (1.9142)^2 = 857.822 joules

From the above result it is evident that the energy exerted by the face kick is greater than the energy of the punch
Comparing (1) and (3)
(i.e.) 522.954joules greater than middle punch (2.5 times)

STANCE
Our aim is to analyze the stance by the way it is structured in order to sustain heavy attacks and moves.

How and where the center ofgravity acts

Fig (5) a karateka in front bent stance (zenkutsu-dachi)

The legs are separated in one shoulder width and one leg is shifted back to one and half shoulder width. Front leg should pointing straight and the back leg should be 22.5-30 degree pointing forward.

In this 70% of the weight is shifted to the front leg and the rest (30%) is in the back leg

Both the feet should be firmly in ground.

Taking this position will give one a better balancing in a combat situation.

VI. COMPAIRSON

So we have calculated the energy exerted by various techniques. Varying the mass several conclusions can be drawn and strategy can be obtained using mathematical calculations

Let us take a scenario that X and Y weighs 70 and 50 respectively keeping the their velocity as invariant

So the energy exerted by Y (with 50 as mass)

MIDDLE PUNCH	= 258.945 j
MIDDLE BLOCK	= 330.6 j
FACE KICK	= 600.48 j

So for Y to meet X, Y should be satisfy the following

22.6 %	faster in punch
31.61 %	faster in block
29.9 %	faster in kick

Since mass cannot vary on instant. The speed has to be increased as above mentioned to equal the power exerted by X

VII. CONCLUSION

Karate is one such form which justifies many of the mathematical property *"the shortest between two points is a straight line"* hence many of the hand techniques is taking the least path from the attacker to the point of impact *"In terms of self-cultivation, one must train from a state of movement towards a state of stillness"* Karate is not just a martial art it is a way of life. My project in terms of giving mathematical values (in joules unit) will justify the brutal and powerful form of the art which can be used to defend oneself in such situation. *"Karate and mathematics is easy. The hard part is being good at it."*-SENSEI.P.ASHWINSHORIN-RYU

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