THE CROQUET ASSOCIATION

Project Croquet Dynamics

NOTE.. This is version 4 of this report. The only change from version 3 is that cross-references have been updated to refer to the 6th edition of the GC Rules and 7th edition of the AC Laws.

1. Introduction

This is a report on the work carried out by a small project team at the Bowdon Croquet Club in September 2006 to investigate the dynamic of various types of croquet shots. The main tools employed were a very high speed and a standard video cameras and video evidence forms a major part of this report. The project was sponsored by the Croquet Association. The report consists of this document plus a DVD containing numerous video clips which are described in this document.

Before release of the report, all the evidence was looked at in detail by both our Association and Golf Croquet laws committees and their summary is appended to the end of this report.

2. The Project Team

This was led by Bill Arliss who initiated the project to attempt to solve some specific problems for Golf croquet referees. Barry Keen provided specialist input from the AC laws committee. Alan Pidcock acted as general technical advisor on test procedures and Ian Lines gave his services as a general and consistent mallet swinger. Pam Arliss acted as project secretary.

The high speed filming equipment was provided by high speed video consultant, Mark Johnson who trades under the name of 'Slow Mo'. Mark is a sports analyst and is normally associated with horse racing. I am very grateful that Mark took due note of the CA's very amateur status and provided his services at less than 30% of the normal commercial charge.

Thanks must also be given to the Bowdon Croquet club who provided lawn services free of charge.

3. The Aims

It is hoped that by gaining a much better understanding of the mechanics of various croquet shots by looking at them at very high speed we shall be able to give all our referees, both golf and association croquet, a better understanding of how to interpret the various sights and sounds that the human eye and ear can easily recognise when judging the validity of any croquet shot. This is specifically important for our Golf Croquet referees as we are still in our infancy on training for this specific duty.

4. The Tests

All the shots were identified by a test identifier that is used throughout the narrative and all the film clips. There are six series of tests starting with the letters A through F for each type of shot. The series were

A	single ball shots
B	double tap situations with two balls
C	normal two ball croquet strokes
D	hoop running starting from close to hoop
E	hammer shots
F	jump shots

5. The Video Clips

The special camera was capable of taking clips at up to 16,000 frame/sec however we decided that a maximum of 8,000fps was sufficient for all our needs. Some in fact were taken at 1000fps. At the higher resolution, the actual size of the video clip is considerably reduced in height so a long thin clip is obtained. When the raw files are played in any normal form of computer media player, the replay rate is 24 fps dependent on the processor rate. However with the software that we were given by the video consultant, each file can be played at different rates right down to 1 fps. Each frame is annotated with the camera frame speed and the frame number. The special software also allows us to move through a clip frame by frame on demand. This in its turn allow accurate speed measurement of both balls and mallets which has been recorded in this report.

All of the clips included on the DVD are recorded at the normal 24 fps but you will find that most media players offer a slow playback. This option may be best for viewing the high speed clip Also most players offer repetitive play as an option,

6. Single Ball Shots- Series A

A total of eight shots were made in this series, half as straight drives and half as roll shots. The difference between each shot was the strength and ball movements of between 1 and 50m was obtained. The camera speed for each of these clips was 8000fps. Very little is learned from viewing the high speed clips themselves. The main information comes from the detailed analysis, especially the contact times and distances which proved to be a good guide as to what would happen with other types of shot. As will be seen from the standard video clips, ball have to be hit quite hard to reach 5mm contact distance.

Single Ball Shots					
Test No	Ball Travel	Mallet Speed m/s	Ball Speed	Contact dist. mm	Contact time msec
A1D	0.93	0.78	1.04	1	1.4
A2D	9.74	3.20	4.31	2	0.9
A3D	24.73	5.23	6.86	4	0.9
A4D	45.85	8.18	8.62	5	0.9
A1R	1.18	0.76	0.71	1.5	3.4
A2R	7.15	2.90	2.87	3.5	1.9
A3R	22.76	4.74	3.92	4	1.5
A4R	44.12	7.43	7.00	4.5	1.1

7. Two Ball Double Tap Situations – Series B

This is particularly important to Golf Croquet where all double taps are illegal. It happens many times in each and every game as players try to remove their opponent from a hoop whilst staying there themselves. Clearance has to be along the line of centres as angled shots remove both balls which is not the object of the exercise.

All shots were played as stop shots which is the logical approach and all were hit along the line of centres. The variations from shot to shot were the initial distance between the two balls and the strength of the shot itself.

As expected the cases where balls started quite close to one another did not show double taps as the mallet and strikers ball were still in contact when contact was made with the second ball. In such cases it is quite possible to get a travel ration of 3:1 or under and still avoid a double tap. Once the initial clearance exceeds say 6mm but say less than 12, all the shots photographed were double taps. Under these circumstances the travel ratio was 4:1 or less. As initial clearances get even greater it become almost possible to hear the double tap and the difference between clean and faulty shots travel ratios is extremely clear. Compare for example B4MS and B6MS.

Two ball double taps						
	Front Ball	Back Ball	Mallet Speed	Ball Separation	Ratio	Comment
B1GS	2.70	0.64	1.74	1mm	4.2	No DT but fault
B2GS	2.61	0.77	1.62	6mm	3.4	Double tap
B3GS	3.10	0.8	1.88	13mm	3.9	Double tap
B4GS	2.20	0.06	1.52	33mm	36.7	No fault
B1MS	15.90	2.45	4.85	1mm	6.5	No DT but fault
B2MS	18.64	6.7	5.57	6mm	2.8	Double tap
B3MS	16.07	5.75	5.13	13mm	2.8	Double tap
B4MS	22.07	5.93	5.74	33mm	3.7	Double tap
B5MS	24.10	0.49	4.99	33mm	49.2	No fault
B6MS	13.43	0.37	4.33	33mm	36.3	No fault
B7MS	6.40	0.7	2.48	13mm	9.1	No fault
B8MS	48.10	19.35	8.87	13mm	2.5	Double tap
B9MS	49.60	16.5	9.68	1mm	3.0	No DT but fault
B10MS	42.25	16.9	10.64	2.5mm	2.5	No DT but fault
B11MS	54.30	17.72	8.76	5mm	3.1	Double tap
B12MS	52.30	21.9	10.32	4mm	2.4	Double tap

Where "No DT but fault" is used in above table, the fault refers to the new laws 11.2.6 in GC and 29.1.7 in AC

8. Normal Croquet Shots

In this series the following suffixes were used to describe the shot type.

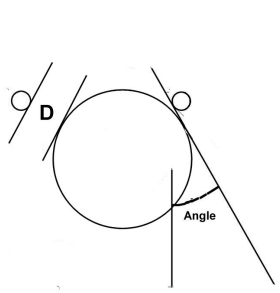
D –drive
H – half roll
F – full roll
P – pass roll
S – stop shot

All clips were filmed at 8000fps.

	Front Ball	Back Ball	Mallet Speed	Contact Time msec	Ratio
C1D	6.21	1.55	2.80	2.5	4.0
C3D	16.17	5.35	4.66	2.5	3.0
C10D	30.80	8.02	7.17	2.1	3.8
C1H	2.38	1.7	1.75	57.8	1.4
C3H	7.67	3.12	3.25	41.3	2.5
C10H	18.00	7.83	6.35	46.9	2.3
C1F	1.21	1.21	1.12	34.9	1.0
C3F	4.39	3.66	2.66	30.4	1.2
C10F	10.50	8.49	4.95	35.5	1.2
C25F	25.10	20.27	7.31	32.9	1.2
C3P	4.51	3.73	3.10	37.4	1.2
C10P	9.76	10.35	4.88	42.8	0.9
C25P	30.00	26	HS file corrupt		1.2
C3S	4.85	0.78	2.15	2.5	6.2
C10S	10.61	2.52	3.44	2.6	4.2
C20S	22.26	5.48	6.76	2.4	4.1

9. Hoop Shots with balls close to wire

The distance D and angle describe the starting positions in accordance with the diagram below.



Most of these clips were played with a fairly hard shot and no attempt was made to hold back with the mallet. The high speed clips clearly identify where faults occurred. It is considered that the standard video shots also provide good information with the exit from the hoops being either very slow or angled to the striker's left when faults occurred. These clips were taken at 1000fps

	Shot	Dist D	Angle	Comment
D1	Medium	56mm	30	Clean shot
D2	Hard	56mm	30	Clean shot
D3	Hard	33mm	30	Clean shot
D4	Hard	19mm	30	Clean shot
D5	Hard	13mm	30	Clean shot
D6	Hard	33mm	40	Clean shot
D7	Hard	35mm	42	Clean shot
D8	Hard	45mm	52	Fault, F/N/M/F/N/M triple tap
D9	Hard	38mm	38	Fault, N/M/F Exit 20 degs to left
D10	Hard	38mm	45	Clean shot
D11	Hard			Near wire deliberate, fault N/F/N/M/FC/M slow out
D12	Hard			Clean, N/F/N Too far away for double tap
D13	Hard			Clean, N/F/N Too far away for double tap

10. Hammer Shots

These shots were taken with the ball either 150 or 300mm away from the hoop. It should be pointed out that ground conditions were quite soft at the time of the tests. Certainly the two shots close to the hoop resulted in the ball being squeezed out from between the mallet and the ground. The standard video also shows no sign of a jump. However the contact time between mallet and ball is less than 30 msecs in both cases which is small when compared to many roll shots. The less steep angle of attack gives a shot which shows a small jump on exit from the mallet (see standard video) however in all cases there are clear signs of a double tap.

	Ball distance from hoop mm
E1	150
E2	150
E3	300
E4	300
E5	300
E6	300

11. Jump Shots

Two aspects were looked at in this series, the hoop deflection and the actual shot. In clips F1, 5 and 6 the high speed camera was focused on the hoop itself. It would appear from all the clips that none of the jumps shots in any way infringed the laws of the game. The jump I have described as Egyptian style is one that is normally used by the Egyptians when they have need of a jump. It appears to be nothing more than a drive but the hands lead the head of the mallet head sufficient to give the downward force to make the ball jump. It is extremely effective at 6 to 8 feet.

	Type
F1	Jump –hoop deflection
F2	Straight
F3	Straight
F4	Deeper angle
F5	Higher jump – hoop deflection
F6	Higher jump 9.3cm – hoop deflection
F7	Close jump shot
F8	Egyptian jump

12. Rolling Tests

These are labelled as series K and were not intended for laws queries. It was simply a case of determining how quickly a ball converts from sliding action to full rolling action. No analysis of these shots has yet been completed.

Bill Arliss

Test Coordinator.