The String is the unknown quality.

Today's string-market.
There is huge amount of strings on the market today and it is quite difficult for stringers to find the best strings for different types of players. Besides, string manufacturers do not advertise the most important specification of their strings, it is like offering a car without telling how many seats are inside.

In the old days there was a saying that was used to advise a new string; "this string plays like gut".
Manufacturers tried to copy the gut string because that was the only real string.
When a player hits a ball he feels the way that a string stretches and how it accelerates the ball in the opposite direction. These properties depend fully on the elongation character of a string.
It is impossible to copy the playability of gut strings, because it seems impossible to copy their elongation quality.
And perhaps that is the reason that string manufacturers did not like to tell the specs of their strings, it would tell the world that the new strings are not as good as gut after all.

The elongation figures of a string show the most important quality of a string, it shows what the player feels on ball impact and also has an important influence on the durability of a string. Besides, the loss of tension during stringing and playing depends on the elongation quality of strings.

Classification of strings based on the elongation figures.
String suppliers offer many types of strings and most of these strings in different gauges.

But what is the difference that the player actually feels?
And is it really useful to offer strings in gauges with a difference of less then 10 %?

The answers to many questions about strings come from their elongation tests. Like with metals it is quite easy to measure the elongation character of strings, a stringer can actually perform a simple test on his stringing machine.
The elongation test with strings can be done in a simple, but also a more scientific way by making a complete graph.

The figure 1 shows the elongation graph of a string. To show the qualities during play the test must be done from the lowest stringing tension upwards:
The horizontal axis show the elongation of the string in %, the vertical axis shows the tension in lbs.

The string is tensioned from 44 lbs to 88 lbs while the elongation is measured, after reaching 88 lbs the tension is lowered to 44 lbs again. The speed of pulling is low (1 to 2 lbs/second) so that all the elongation in the string can be developed.

The graph shows the following figures:
- The total elongation of the string from 44 to 88 lbs is 6,7 %.
- About 2 % of the elongation has "sprung back" after lowering the tension to 44 lbs, this is the elastic elongation, the actual elasticity of the string.
- After reaching 44 lbs the string is 4,6 % longer, this is the elongation that did not recover it stays in the string after the first pull, this is the remaining elongation.

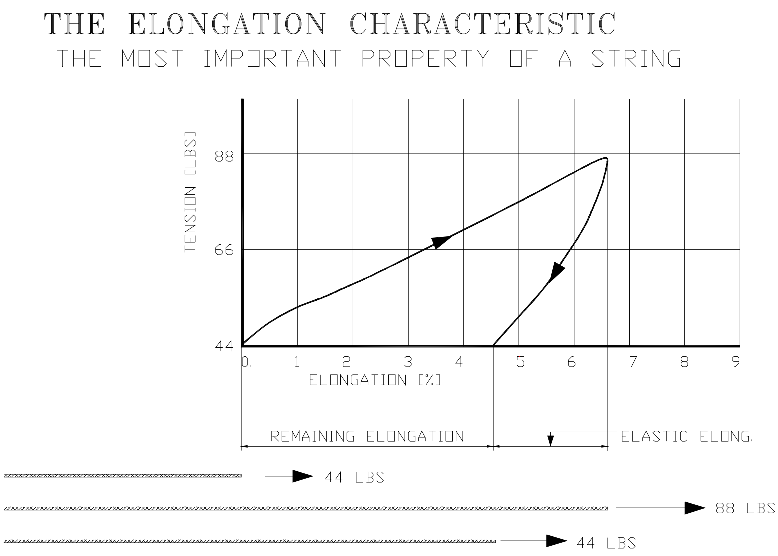


Fig. 1

When this string is tested again the elongation will be much less because the remaining elongation that has developed during the first pull will not develop again.

For every string counts that there is a certain amount of elongation with every tension in the string.

Simplified elongation test.
It is not necessary to measure a complete graph to obtain the major elongation figures of a string, one can also do a "5 point-test". Tension the string on 44 lbs and change the tension from 44 to 66 to 88 and back to 66 and 44 lbs. Measure the elongation at each tension and calculate the different elongations with these results. It is important to measure the elongation at 66 and 88 because it can show the difference in character of a string in the lower and higher tension range.
Many monofilament strings show a completely different character at higher tensions compared to the lower tensions.

Figure 2 shows a simplified but very accurate test setup. The tension is generated by a CP drop weight system, which is very suitable because it is easy to raise and lower the tension accurately. The elongation is measured with a linear potentiometer mounted inside the test tool which is simply clamped to the tested string. The display of the Tennis Computer shows the elongation figures.

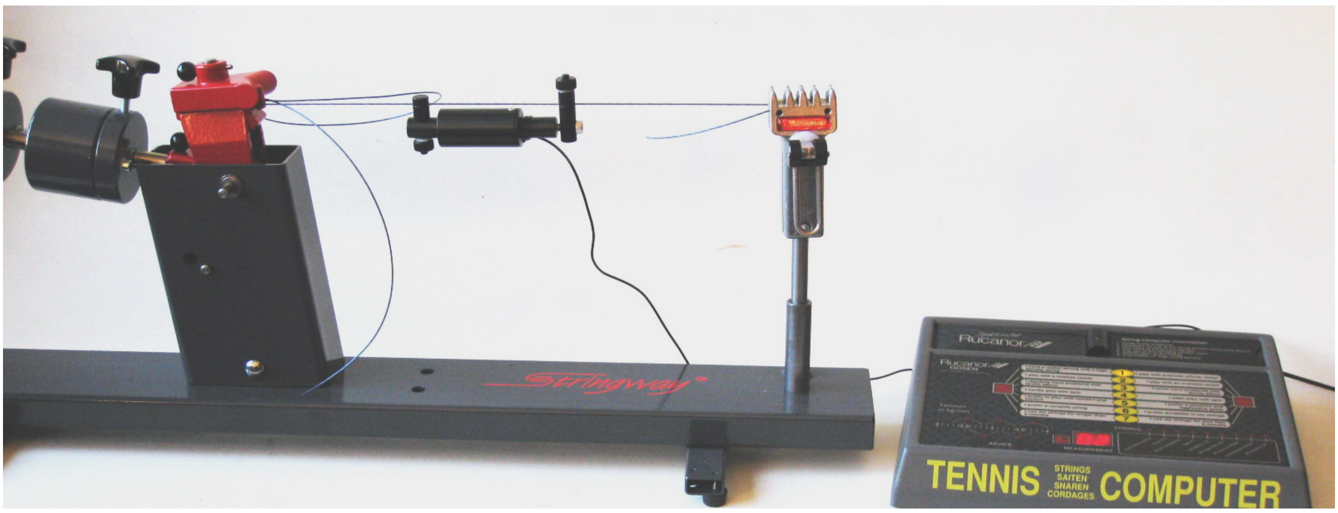


Fig. 2

To test strings on the stringing machine.

The same simplified test can be done by a stringer, preferably on a drop weight machine but otherwise on a good " constant pull" electronic machine:

Tension a length of string at 44 lbs and make 2 marks on the string at a certain distance. The bigger the distance the more accurate the test. Raise the tension to 66 and possibly 88 and measure the length between the marks. Then lower the tension back to 66 and 44 and measure again.

If you calculate the elongation in every situation you can calculate the different elongations as shown in the table below.

Of course it is not of major importance to use 66 and 88 lbs, it is important to compare strings at the same tensions.

Take care that the test is done with a virginal piece of string!

Many different strings.

Figure 3 shows different strings which are in the market, a stiffer string suitable for spin play, a more convenient string and a useless string with huge elongation but no elastic elongation at all.

Figure 4 shows the elongations of some mono strings and figure 5 of a number of nylon multi strings.

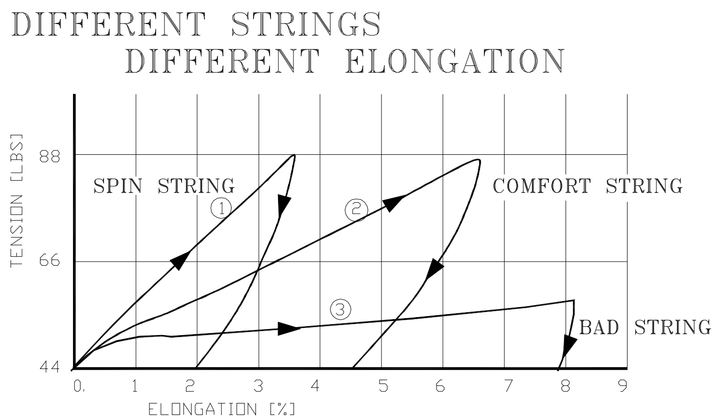


Fig. 3

The player feels the stiffness of the string.

Except the elongation figures the table also shows the stiffness of the strings in the blue column. The stiffness is shown in lbs/in for a length of string of 320 mm. The same stiffness is shown in the String selector of the URSRA.

The stiffness is calculated by dividing the total elongation from 44 to 66 lbs by the difference in tension (22 lbs).

Elongation>>	ELASTIC EL.		REMAINING EL.		TOTAL EL.		STIFFNESS
	[%]	[%]	[%]	[%]	[%]	El.inde:	lbs/in
Tension>>	44>66	44>88	44>66	44>88	44>88	el/tot	44>66
STRING							l=320 mm
Prof Supreme Power	0,8	1,2	3,6	6,7	7,9	0,15	40
Wilson Enduro Tour	0,7	1,1	3,6	6,1	7,2	0,15	41
Prof supreme power	0,6	1,1	2,9	5,7	6,8	0,16	50
Toro	0,6	0,9	2,0	5,8	6,7	0,13	67
Pros Pro Cygber power	0,8	1,2	1,5	4,3	5,5	0,22	76
MSV Focus Hex	0,7	1,1	0,6	3,2	4,3	0,26	134
Oehms black pearl	0,7	1,1	0,5	2,5	3,6	0,31	146
Babolat Pro Hurricane	0,6	0,9	0,6	2,6	3,5	0,26	146
Prof Dual Metal	0,6	1,0	0,2	1,8	2,8	0,36	218
Orkit Fluo qua	0,5	0,8	0,1	0,8	1,6	0,50	291

Fig. 4 Elongation of mono strings.

Elongation>>	ELASTIC EL.		REMAINING EL.		TOTAL EL.		STIFFNESS
	[%]	[%]	[%]	[%]	[%]	El.index	lbs/in
Tension>>	44>66	44>88	44>66	44>88	44>88	el/tot	44>66
STRING							l=320 mm
Technifibre Duramix	1	1,6	1,5	2,9	4,5	0,36	70
Mailot Salvarez HT Ten	1,1	1,8	0,7	2,1	3,9	0,46	97
MSV Multi g 10	1,1	1,8	0,8	1,9	3,7	0,49	92
Wilson Sensation	1	1,6	0,7	1,6	3,2	0,50	103
Technifibre Multifeel	1,0	1,7	0,6	1,4	3,1	0,55	109
Luxilon Luxifit	0,9	1,6	0,5	1,2	2,8	0,57	125
Prince Tournement	0,9	1,5	0,5	1,2	2,7	0,56	125
Kirschbaum Touch Titar	0,9	1,6	0,2	0,9	2,5	0,64	159
Head Fibergel	0,9	1,5	0,3	0,9	2,4	0,63	146
Gosen Micro	0,8	1,4	0,1	0,8	2,2	0,64	194

Fig. 5 Elongation of multi strings.

The figures show that:
- The difference in total elongation of the mono strings is huge, from 1,6 to 7,9 % (green column).
- **T**he elasticity (yellow column) of all multis is considerably better than of any mono.
- There is a big difference in stiffness in both type of strings (blue column).
- The remaining elongation of many monos over 66 lbs is huge. (difference between both white columns).

"Fast" strings and "slow" strings.

There is one more important item concerning the elongation of strings; there are fast strings and slow strings.

With "fast" string it takes little time to develop all the elongation for a certain tension, with "slow" strings it takes much longer.

The elongation develops slower when there is a more friction inside the string, either between the filaments of the multi filament string or internally in the material of the mono filament string.
A fast string (with a certain amount of elastic elongation) will give more power than a slower string with the same amount of elasticity.
The speed of a string can be noticed on a stringing machine because a slow string needs more time before all the elongation has developed.

The meaning of the elongation figures in the tennis-praxis.

The meaning of the different types of elongation in tennis praxis are:
* More elastic elongation:
- More power, this is the actual elasticity of a string that generates the speed of the ball.
- Better recovery after a spin stroke.
- Better behoud maintenance of the tension in the racquet.

* More remaining elongation:
- More loss of tension during play.

* More total elongation:
- Longer ball contact resulting in more comfort.
- Worse durability, because the string will move up and down more with a spin stroke.

It is important to know that the behaviour of any string strongly depends on the Stringbed stiffness in the racquet and the actual tension in the string in the racquet.
The level of tension and stiffness can make and kill the qualities of any string.
The influence of String- bed-stiffness (tension) and string elongation will be described in a later chapter.

The “elongation” of a string during ball impact is more explainable when the deflection of the string bed is divided in an inward and an outward movement:

* During **the inward movement** of the ball into the string bed, the ball is actually caught by the strings.
- The amount of deflection depends fully on the SBS, the lower the SBS the more deflection of the string bed. The amount of elongation of the string will grow progressively with the deflection of the string bed.
- Remaining and elastic elongation will be developed in the string, during this movement, the tension in the string will rise. When the tension rises above the tension that it has ever reached before some remaining elongation will occur. Because the time of the impact is very short not all the remaining elongation belonging to this maximum tension will be developed.

So the string needs a number of hits to develop all the elongation at a certain tension. Once the maximum tension during a hit does not rise anymore the loss of tension will decrease.
This is why strings loose most of the tension during the first hour of play.
- The deflection will be smaller with a string with less total elongation, because the stiffness is higher. This results in a shorter dwell time (duration of contact) and a bigger “impact-force”.

* During the **outward movement** the ball will be “catapulted” away by the string bed.
- The amount of acceleration depends mainly on the elastic elongation of the string. The friction inside the string will have some influence on the power that a string offers. If there is more friction in the string there will be less power, the string will “spring back” slower.

The influence of the elongation during stringing.
When stringers aim at a certain stiffness (“stringing on stiffness”) it is important to know the influence of the properties of the string on the stiffness result after stringing. “To string accurately” means “loosing as little tension as possible”.

* Fast strings and slow strings.
For every string counts that there is a fixed relation between the amount of elongation and the tension in the string.
Depending on the friction inside the string-construction or material certain strings can stretch very quickly and others need more time before all the elongation has developed in the string.
When a stringers clamps a string before all the elongation has developed the string is still stretching behind the clamp and the string will loose tension.
That is why there is a saying in the stringing world: “Fast stringers are soft stringers”.

The speed of stringing depends upon the type of string, and if you want to string fast you have to use fast strings.

* The elastic elongation maintains the tension.
When you tension a rope between 2 walls it is nearly impossible to keep it tight, when the rope does not stretch.. It is very easy to get a piece of elastic band tight.

The elastic elongation of a string maintains the tension in the racquet.

The final stiffness in the racquet will be lower with Strings with less elasticity, the sbs with syn gut will be considerably higher than with any mono.

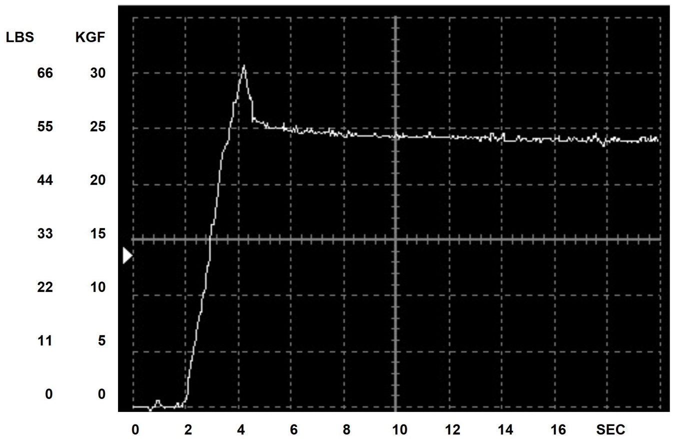
* Second pull less travel.
When a string is tensioned for the second time the elongation is much less, because the remaining elongation has been developed in the first pull already.
When stringing a stretchy string the travel of the tension system may be too small to reach the tension in one pull. Pull tension again without moving the clamp and the travel will often be ok then.

* A lot of travel means a lot of elongation.
When a string is tensioned the travel of the tensioner depends on the stiffness or total elongation of the string. When a string needs more travel it means that it is a string with a lower stiffness, so the stringer should know then if this string is suitable for a certain player or not. (As described above).

* Prestretching creates a stiffer string with different playability.
When a string is prestretched, the machine pulls higher then the set tension before going back to the set value. This means that the remaining elongation has been pulled out of the string at a higher tension. The result is that the string is stiffer, offering less power, but the string also looses less tension.

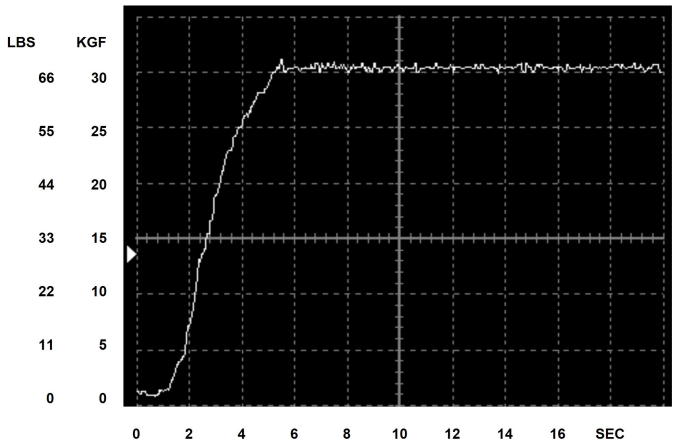
* A lock out machine always pre-stretches the string, which means different playability!

LOCK OUT TENSIONER WITH NYLON MULTIFILAMENT STRINGS.



LOCK OUT; NYLON 1,8 / 4,2 % / 20 KGF. TENSION LOSS = 8 KGF (17,6 LBS)

"SMART-WEIGHT" TENSIONER (SW M90)



MS150 MONOFIL. 1,1 / 8,4 % / 20 KGF. NO TENSION LOSS

When a stringer aims at a certain SBS he needs more tension on a lock out tension unit then on a constant pull unit. The graphs show the tension on a lock out machine and on a CP drop weight machine.
On the lock out machine the string has been tensioned to about 67 lbs and the final tension is about 53 lbs. The string is actually pre-stretched to 67 lbs before finally stabilizing at 53 lbs. This means that a certain amount of the remaining elongation at 67 lbs has been developed and the string has become a stiffer string.

The tension on the CP machine is never higher than the final tension in the string. I.o.w;. If the final tension in the string should be 53 lbs, the tension will never exceed that tension on the CP machine so the string offers more playability (comfort) then the string bed created on the Lock out machine.

* Drawback of the clamps causes more loss with stiffer strings.
When the string is released by a tension unit the clamp will move backwards under the load of the string, this is called “drawback”. Part of the drawback will “recover” at the next pull.
The remaining drawback after the next pull causes loss of tension in the string.
When you multiply the drawback and the stiffness of the string the result is the loss of tension.

So the stiffer the string the more loss of tension is caused by the drawback of the clamp.

Other major specifications of strings.
When strings should be selected for different types of players there are other properties which play a part:

* The breaking strength.
When a string breaks at a higher tension the string can wear down further before it brakes, so a higher breaking strength raises the durability. Mono filament strings have a higher breaking strength than multi filament strings and Kevlar is very strong also.
The difficulty with multifilament strings is to divide the total force equally among the core and the smaller filaments around the core.

* The wear-off resistance.
The wear off resistance is a major factor in the durability of strings. When strings are used for spin play the main strings slide up and down all the time, resulting in a wear hole in the main strings at every crossing with a cross string.
Mono filament or solid strings have the highest resistance against wear and soft core strings wear very quickly especially after the shell has been cut through.

* The diameter of strings.
Most tennis strings are available in many gauges from 1,1 to 1,45 mm. It is important to understand that there is not much connection between the playability of strings and the diameter. The material and the construction of strings have a much large influence on the playability then the diameter.
Of course it must be so that thinner strings of a certain type stretch more than the thicker strings of that type.

The table shows monofilament strings of 2 gauges, 1,25 and 1,3 mm. Only the material of these strings is different and the design is the same, all being massif monos. Despite the fact that the diameter is the same the stiffest string is nearly 4 times stiffer than the most stretchy string.

The conclusion can be that the diameter of strings is a bad standard for playability.

	Elongation>>	ELASTIC EL.		REMAINING EL.		TOTAL EL.		STIFFNESS
Gauge		[%]	[%]	[%]	[%]	[%]	El.index	lbs/in
mm	Tension>>	44>66	44>88	44>66	44>88	44>88	el/tot	44>66
1,25	Speedstring Blacl Rev	0,7	1,2	3,4	6,4	7,6	0,16	43
1,25	Discho Iontec	0,6	0,9	1,6	3,6	4,5	0,20	79
1,25	MSV Hepta Twist	0,8	1,3	1,3	4,2	5,5	0,24	83
1,25	MSV Focus Evo	0,7	1,1	1,3	3,0	4,1	0,27	87
1,25	Babolat Pro Hurr -2	0,7	1,0	0,8	5,1	6,1	0,16	116
1,25	Babolat Pro Hurricane	0,7	1,0	0,7	5,0	6,0	0,17	125
1,25	Signum Hextreem	0,7	1,1	0,4	2,2	3,3	0,33	159
1,3	Prof Supreme Power	0,8	1,2	3,6	6,7	7,9	0,15	40
1,3	Wilson Enduro Tour	0,7	1,1	3,6	6,1	7,2	0,15	41
1,3	Toro	0,6	0,9	2,0	5,8	6,7	0,13	67
1,3	MSV Hepta Twist	0,7	1,1	1,6	3,7	4,8	0,23	76
1,3	MSV Evo Hex	0,5	0,9	1,0	2,5	3,4	0,26	116
1,3	Bab Pro Hur tour	0,6	1,0	0,8	1,7	2,7	0,37	125
1,3	Babolat Pro Hurricane	0,6	0,9	0,6	2,6	3,5	0,26	146

When strings are classified for different players, the diameter can be used to select strings for certain racquets. Thinner strings can be used for high density string patterns and stronger and thicker strings should be used for low density patterns.

Classification of players:
When a racquet tuner should be able to tune the string bed to the type of player with the choice of the string and the stiffness of the string bed he needs criterion to classify players and to classify the strings.
This classification can be done based on the preference of the player, how he or she hits the ball and if he or she has any arm injuries.
We can make the following division:
LADY/ MAN,
COMFORT PLAY / POWERFUL PLAY
WITH SPIN / WITHOUT SPIN
ARMINJURY
UNDER OR OVER 16 YEAR

Classification of strings.
When strings have to be classified for the different players the following specifications can be used:
- The string elongation, influence as described above.
- The string stiffness, stiffer strings for durability and less power, more stretchy strings for more power and comfort.
- The breaking strength in the interest of high durability.
- The wear off resistance for high durability also.
- The diameter to adjust to the density of the string bed.
- The maximum stringing tension based on the remaining elongation.

Strings which loose a lot of tension at higher tensions can be the best for low tensions. These strings have much more remaining elongation from 66 to 88 lbs then below 66 lbs.

Based on these specs the strings can be classified in 4 classes:

S1 string for comfort players or players with arm injuries:
A string for comfort play should stretch more for longer ball contact and have a good elasticity to supply the power. Durability is not important
String: Total elongation more than 4 % (44-88 lbs), good elasticity, durability unimportant.
Maximum stringing Tension: 60 lbs.
Stringbed stiffness: Between 28 and 34 kg/cm (dt value).
Tension: can be calculated from the stiffness when the size of the racquet and the number of strings is known.

S2 string: All round players:
This should be an all round string with very good playability but stiffer than the S1 type. Durability is better then the S1 string.
String: Total elongation 3,3 to 4 %, good elasticity, reasonable durability.
Maximum Tension: 65 lbs
Stringbed stiffness: 33 to 36 kg/cm (dt value)
Tension: can be calculated from the stiffness when the size of the racquet and the number of strings is known.

S3 string: Spin players who prefer playability:
This string combines good playability with good durability. It is stiffer than the S2 string and has a better wear off resistance.
String: Total elongation 2.8 tot 3,2 %, good durability.
Maximum Tension: 75 lbs
Stiffness: 36 to 38 kg/cm.
Tension: can be calculated from the stiffness when the size of the racquet and the number of strings is known.

S4 string: Spin player who prefers durability:
This string is for spin players who prefer a maximum durability. It combines low elongation with maximum strength and a high wear off resistance.
String: Total elongation 2.0 – 2,8 %, high durability.
Poly strings or Kevlar/ nylon combination.
Maximum Tension: 75 lbs
Stiffness: 38 – 40 kg/cm
Tension: can be calculated from the stiffness when the size of the racquet and the number of strings is known.

Analysing the players.
The Stringway route maps is a system which helps to analyse players in order to choose the right string and SBS. The right string and stringing stiffness is selected based on the answers to the questions.
The strings are indicated with “C” instead of “S”.

The age of the player is not in this system but should play a role also. Young kids should play with a more “convenient” string bed, comfort string at lower SBS, to prevent injuries and so that they learn to use the power out of the stringbed. Lower the “calculated” stiffness by 1 stiffness class (3 kg/cm) for children under 16.

Keep in mind that today's pros play at relative low stiffnesses (Federer at 34 kg/cm) so that they can use the power of the string bed to lift the speed of their game.

The relation between the stringbed stiffness and the stringing tension will be explained in a later version of this series.