Chapter Four

A COMPARISON OF SHAFT FREQUENCIES

Key terms for understanding the information contained in Chapter 4:

Bend Point - The point of maximum bending on a shaft as measured by compressing one end of the shaft toward the other.

Cut Shaft Length - The length of a shaft after it had been trimmed and installed in a golf club.

Deflection - The deviation of the tip from the butt centerline after a known unit of force is applied to the tip to create a curve in the shaft.

Frequency - The number of oscillations a shaft makes over a known period of time after the tip is pulled down and released while mounted in a special frequency-measuring device. Measured in cycles per minute (cpm)

Kick Point - The point of maximum bending on a shaft as measured by deflecting the tip end of the shaft with a constant weight or force.

Pattern - The design of a particular shaft, indicating the distribution of flexibility about the shaft. Pertaining to this shaft testing project, pattern designates a particular model of shaft, e.g. Dynamic, Phoenix, Microtaper, Low Torque, etc. are all names that describe different shaft patterns.

Quantitative Measurement - As pertaining to the shaft testing project, a test result that can be expressed in a numerical measurement.

Raw Shaft Length - The length of a shaft as it is manufactured, before trimming and installation into a golf club.

Relative Stiffness - The stiffness of a shaft when compared to other shafts.

Seamless Shaft - A steel shaft produced from a non-welded, seamless drawn tube.

Welded Shaft - A steel shaft produced from a continuous strip of steel that had been longitudinally coiled and welded into a tube.

Shaft vibrational frequency is a quantitative measurement of the rate of vibration (oscillation) of a shaft as expressed over a known unit of time. In the late 1970's a few individuals began working on developing a way to identify a quantitative measurement of shaft stiffness to be able to ensure a more accurate progression of stiffness through sets of golf clubs. Vibrational frequency became a viable method for more accurately identifying such a relationship because it was a quantitative measurement which took some of the shaft's bending properties into account.

Determining just who was the "father" of modern shaft frequency measurement is a subject for debate. While the "who" is not certain, it is clear that the concept first was applied on both sides of the Atlantic in the mid-1970's. John Kilshaw, an engineer working for Dunlop's European golf equipment division, first began using shaft vibrational frequency measurements in an effort to develop a uniform progression of shaft flexibility from club to club within a full set. Both UK and U.S. patents were issued for Kilshaw's conceptual development. Dunlop's UK division did establish a limited distribution of frequency-assured sets of golf clubs, which the stiffness decreased from the long to the short clubs, a worldwide effort to promote this method of shaft matching in an effort to merchandise the company's golf equipment was not mounted at the time.

In the late 1970s, a U.S. patent was issued to Dr. Joseph Braly of Kennett Square, Pa., which disclosed a method for manufacturing sets of frequency-matched shafts. Unlike Kilshaw's patent which dealt with fully built golf clubs, the Braly patent outlined methods for turning shaft "blanks" into vibrationally-matched sets of shafts and served as the origin for a steel shaft design which is now known as the Royal Precision (formerly Brunswick) FM pattern. An important point in this study, neither the Kilshaw and Braly patents fully described or outlined the use of frequency measurement as a means of comparing different patterns and flexes of shafts for the purpose of defining shaft flexibility.

To measure the frequency of a golf shaft, a machine must be employed which is able to count the number of oscillations of the tip end of the shaft over a known period of time while the butt of the shaft is secured. While deflection is considered to be a static measurement of shaft flex, vibrational frequency is the only method yet devised for obtaining a more excited, or dynamic, determination of shaft relative stiffness. In comparative terms, the faster the rate of vibration of a shaft, the stiffer is the flex; and the lower the frequency reading, the more flexible the shaft is considered to be. Because this form of dynamic flex measurement includes the presence of actual clubhead weight, playing length and a grip - conditions a golfer finds in his finished clubs - the frequency measurement of the shaft within a finished golf club becomes the best method available for quantitatively rating the flex.

The reason shaft vibrational frequency is considered to be a more accurate and practical way to identify and compare the flex of different shafts, is because the test can be performed on a finished golf club, taking the following flex affecting factors into account:

Shaft Flex (Relative Stiffness)

Within a particular shaft pattern, the greater the stiffness, the higher the frequency; conversely, the more flexible the shaft within a single shaft pattern, the lower the frequency.

Shaft Length (Playing Length)

Within a particular shaft pattern and flex, the longer the cut length of shaft within the club, the lower the frequency; conversely, the shorter the cut length of shaft within the club, the higher the frequency. Therefore, as golf clubs get longer, the frequency of the shaft decreases, indicating a decrease in stiffness. And, as golf clubs get shorter, the frequency of the shaft increases, indicating an increase in stiffness.

Clubhead Weight

The higher the swingweight (or the greater the weight of the clubhead), the lower the frequency; conversely, the lower the swingweight (or the lower the weight of the clubhead), the higher the frequency.

Shaft Weight

The heavier a shaft is within a single pattern, the higher the frequency; conversely, the lighter a shaft is within a single pattern, the lower the frequency. As a result, the heavier the shaft within a single pattern, the stiffer it will be and the lighter the shaft within a single pattern, the more flexible it will be.

It is possible to obtain the frequency measurement of shafts without the presence of the clubhead and grip, for shaft-to-shaft comparison purposes. However, it is far more meaningful to concentrate on frequency measurements that have been obtained from tests that are performed on the shafts in their cut form as mounted in finished golf clubs. In the Dynacraft/Apollo shaft testing project, frequency testing was done initially on more than 400 cut shafts after installation into Drivers and #5-irons, with the results recorded in cycles per minute (cpm). As was outlined in Chapter 2, the shafts were trimmed as per each manufacturer's instructions and assembled into a specially altered metal wood Driver and #5-iron head. To assure a standard mounting of each shaft, proper trimming adjustments were made for the shafts to allow for each clubhead's bottom of bore to groundline dimension.

All of the A, R, S and X-flex shafts were tested at men's modern standard lengths for the Driver (43") and #5-iron (37.5"), with each club built to a swingweight of D1 and assembled with a standard size Golf Pride Victory grip. The L-flex shafts were frequency tested at both the modern standard ladies length (Driver - 42", #5-iron - 36.5") at a swingweight of C6, as well as at men's standard length (Driver - 43", #5-iron - 37.5") at D1 swingweight. This meant the actual cut shaft lengths for the test shafts were 41.375" for men's Driver; 40.375" for ladies Drivers; 36" for the men's #5-irons and 35" for the ladies #5-irons. As mentioned in Chapter 3, the L-flex tests were performed at both lengths to help gain a better overall picture of just how the L-flex shafts compared to all of the other traditional men's flex levels.

SHAFT FLEX - A 1992 Comparison of the Frequency Measurements

Since the introduction of the Precision FM steel pattern, shaft frequency has been used more as a marketing tool than for true comparative analysis. As a result, what frequency testing data that has been published has been offered primarily in an attempt to "prove" the superiority of one company's golf club product line over that of another. Never has frequency testing been used in an attempt to inform clubmakers of the comparative differences of a wide variety of shaft designs. From the data collected during the Dynacraft/Apollo shaft testing project, having the opportunity to record and compare the frequencies of more than 400 different steel and composite shafts now will allow more meaningful comparisons to be made between different types of shafts than ever before. The data obtained from the frequency testing will help provide answers to many of the questions about the equality of flexes; whether one particular shaft is truly similar to another; and information to assist clubmakers in making more accurate decisions about fitting the correct flex for their customers.

Every attempt was made to ensure that the frequency results obtained in the Dynacraft/Apollo shaft testing project were as purely comparable as possible. With all the cut length shafts assembled in Drivers and #5-irons which were built to the same finished golf club specifications, a meaningful, and most importantly, a practical comparison of flex can be made. Before disclosing the data and continuing with its analysis, it is important to realize that the frequency comparisons between shafts that will be included in this chapter cannot be considered fitting comparisons. In addition to frequency, there are several other shaft specifications such as deflection, kick point/bend point and torque that must be blended together into the overall discussion before any final fitting recommendations for flex can be made. As such, clubmakers are urged to read this chapter only from a frequency comparison standpoint, and not yet from a complete flex analysis point of view. Later in this book, after the test results for each of the various shaft specifications are analyzed, the most important factors controlling the fitting of flex will be integrated into one definition for making accurate fitting conclusions.

Overall Shaft Frequency Averages for Each Flex

While shaft frequency measurement has been performed since the 1970s, as yet, no real calculations have been made to determine the average frequency for each flex and each shaft material type. As a result, clubmakers and golfers are not entirely aware what measurement of frequency constitutes an L, A, R, S or X-flex for steel or graphite/composite material shafts. Following in Chart 4-1 is an overview of the average frequency for each flex along with the average deviation between the five basic flexes for the wood and iron shafts tested, for both steel and graphite. After recording all of the frequency measurements for all of the cut shafts in the test, an average frequency for each of the flexes within steel and graphite was computed (see Chart 4-1). Once the average frequency for the Drivers and #5-irons for each flex and shaft material type was calculated, it was then possible to use the data to determine the average deviation in frequency between each flex. This was important because the average difference from one flex to the next can be used to determine how many cycles per minute of frequency equates to a full flex level of change. The preceding charts illustrate both of these points, and will be referenced at several points during the ensuing discussion.

Chart 4-1 - 1992 Shaft Frequency Averages by Flex for Steel and Graphite Shafts

Flex	Wood Steel	Wood Graphite	Iron Steel	Iron Graphite
L[1]	235 cpm	248 cpm	290 cpm	290 cpm
A	239 cpm	245 cpm	287 cpm	277 cpm
R	249 cpm	255 cpm	297 cpm	291 cpm
S	260 cpm	269 cpm	308 cpm	306 cpm
X	273 cpm	283 cpm	323 cpm	318 cpm

[1] L-flex measured at ladies standard length for both the wood and iron models.

From studying Chart 4-1, just as in the deflection testing from Chapter 3, it can be seen that the L-flex shafts do not fall in the same progression of frequency as the other flexes. For the L-flex steel shafts that were tested at the ladies standard lengths, the frequency measurements of the steel shafts for both the Driver and #5-iron were actually higher than the A-flex shafts, indicating that L-flex shafts at ladies length actually play stiffer than the A-flex shafts at men's length. When studying the difference in frequency between flexes, logic should dictate that the progression between adjacent flexes for golf clubs should be approximately equal. Looking at the frequency test results for the L-flex shafts at ladies lengths and their deviation in frequency from the A-flex shafts, this is certainly not the case. However, during the time when the initial phase of testing took place, there were only a limited number of A-flex and X-flex graphite shafts in which to calculate a valid average.

The average frequency differences between the steel A and R-flexes as well as between the steel R and S-flexes were very close to 10 cpm, while the stiffness increase from S to X among steel shafts was noticeably greater (13 cpm for Drivers and 15 cpm for #5-irons). The greater difference between the S and X-flexes could be explained by the fact there was fewer X-flex samples to obtain an average.

In contrast to the steel shafts, the graphite shafts that were tested showed a wider frequency deviation from one flex to the next. Again, because of an inadequate number of A-flex graphite shafts in the test, it may not compute a representative separation in frequency between all the flexes. Still, from the data obtained, frequency deviations were calculated from the R to the S-flex and from the S to the X-flex. For the Drivers and #5-irons, graphite shafts displayed a frequency separation between flexes that ranged from a low of 10 cpm to a high of 17 cpm.

Can this data be used to say that graphite shafts have a greater frequency change from one flex to the next than steel? It is unlikely that such a final conclusion can be made, primarily because graphite shafts in general display a much greater degree of frequency inconsistency than steel shafts. During the frequency testing, a number of shafts of different materials and make-up were selected and measured for frequency at four different rotational positions to check for consistency within the same shaft. In other words, each of these shafts was tested at four different shaft positions by rotating the shaft in 90º increments. To allow for fairness and consistency in the test, five samples of each shaft were selected on the basis of dimensional and weight accuracy and rotationally tested for frequency. Chart 4-2 shows the variation in rotational frequency for each of the different shaft construction types - seamless steel, welded steel, sheet-wrapped graphite and filament-wound graphite.

Chart 4-2 - Rotational Comparison of Frequency between Steel, Sheet-Wrapped and Filament Wound Graphite Shafts for Drivers

Shaft	Test	Shaft	Frequency Position				Deviation*	
	Club	Construction	0º	90º	180º	270º	A	B
Aldila	#1	Sheet-Wrapped	279	278	280	277	3	
HM-40	#2	Graphite	284	281	283	281	3	
S-flex	#3		275	275	275	275	0	
	#4		278	277	278	277	1	
	#5		275	275	275	275	0	
								9
Apollo	#1	Seamless	254	253	251	251	3	
AP44 Elite	#2	Steel	254	254	254	253	1	
S-flex	#3		254	254	251	252	3	
	#4		254	253	254	253	1	
	#5		254	254	254	253	1	
								3
Brunswick	#1	Filament-Wound	269	267	268	267	2	
FibreMatch	#2	Graphite	269	269	269	270	1	
FM 6.5	#3		270	269	270	270	1	
	#4		269	268	267	267	2	
	#5		269	267	267	267	2	
								3
True Temper	#1	Welded Steel	259	259	259	258	1	
Dynamic Gold	#2		258	258	258	258	0	
S300	#3		258	257	258	257	1	
	#4		259	258	259	258	1	
	#5		259	258	258	257	2	
								2

*Deviation A represents the maximum range of cpm deviation within the individual shaft. Deviation B represents the maximum range of cpm deviation among the five randomly sampled test shafts of each pattern.

The

findings, as indicated in Chart 4-2, show one significant problem in trying to use frequency as a real indicator of relative stiffness, especially in some of the sheet-wrapped types of composite shafts. For each of the individual steel and filament-wound graphite shafts that were tested at the four 90º rotation positions, the variation in frequency was in a very tight range of 0-3 cpm, as noted in the chart under the column headed Deviation A. However, the high-to-low range in frequency among the five sheet-wrapped graphite shafts that were tested varied by 9 cpm within the same design, as noted under Deviation B. Since the average change between two adjacent flexes of graphite shafts was calculated to be 10-15 cpm, it could be said that some sheet-wrapped graphite shafts may vary by nearly as much as a full flex, from shaft to shaft within the same pattern.

It is also important to note that some sheet-wrapped graphite shafts can display a greater amount of rotational frequency deviation within the same shaft than the HM-40 test results shown in Chart 4-2. To offer proof that the quality of manufacturing is improving to the point of reducing the variation in frequency within the same shaft, Chart 4-3 compares a rotational frequency test of five HM-40 S-flex shafts that were produced in 1989 with five HM-40s made in 1992.

Chart 4-3 - Rotational Comparison of Aldila HM-40 Shafts (1989 vs. 1992 Models)

Shaft	Test Club	Shaft Construction	Frequency Position 0º	90º	180º	270º	Deviation A	B
1989	#1	Sheet-Wrapped	271	269	272	266	6	
HM-40	#2	Graphite	283	284	281	287	6	
S-flex	#3		277	272	280	271	9	
	#4		289	292	289	288	4	
	#5		275	278	271	280	9	
								26
1992	#1	Sheet-Wrapped	279	278	280	277	3	
HM-40	#2	Graphite	284	281	283	281	3	
S-flex	#3		275	275	275	275	0	
	#4		278	277	278	277	1	
	#5		275	275	275	275	0	9

Deviation A represents the maximum range of cpm deviation within the individual shaft. Deviation B represents the maximum range of cpm deviation among the five randomly sampled test shafts of each pattern.

During a late 1989 meeting between Dynacraft personnel and production officials from Aldila, Pete Piotrowski, Aldila's head of research and development, indicated that number one priority for the future, for his company and for the graphite shaft industry, was to improve the axial symmetry of sheet-wrapped graphite shafts. Axial symmetry refers to the consistency of the wall thickness of shafts. If any shaft is made with variations in the wall thickness, it cannot display a consistent frequency when tested in four rotational positions.

As evidenced by the results of rotational frequency testing on Aldila HM-40 S-flex samples made in 1989, the shafts, like virtually all sheet-wrapped graphite shafts at the time, did display a wide range both in the frequency within each individual shaft as well as the consistency of frequency over a test range of five different shafts. Comparing the results obtained from testing the 1989-era HM-40 to the rotational frequency of the 1992 version of the same shaft, it can be seen that a tremendous change has been effected in the production of the pattern to ensure a more consistent product.

Still, what cannot be ignored, despite the vast improvements made to secure greater rotational frequency consistency within each shaft, is the fact that the range between several sheet-wrapped shafts of the same design still varies more than steel and more than filament-wound graphite shafts. Therefore, can the graphite shaft frequency test results in the Dynacraft/Apollo project be considered accurate? Without a doubt, this was a difficult point to address in the overall test philosophy. With more time it would have been possible to test the frequency of every single graphite shaft in the four 90º rotational positions. However, if this had been done, then should the true frequency of each shaft be taken from an average of the four measurements?

Performing a four-position frequency test on each shaft would also have had the effect of identifying the strong and weak side of each shaft. However, it should be noted that since 1991 and until just recently marking the "strong" or "weak" side of any shaftwas not allowed under the Rules of Golf. For test purposes that are to eventually relate to shaft fitting, this would have been of no value for two reasons. First, marking and noting any side of the shaft which performs differently is not allowed, and second, due to the way sheet-wrapped shafts are made, there is no way to know how much variation would exist in any one shaft that a clubmaker might purchase and use in assembly. Therefore, because clubmakers are required to unknowingly deal with frequency inconsistencies among all the sheet-wrapped graphite shafts, and there is no way to know if, or to what degree, this characteristic exists in any particular sheet-wrapped shaft. Performing the frequency tests with the hand-selected shafts installed in the golf clubs at random positions had to be the only acceptable means of obtaining characteristic frequency measurements of the shafts.

Suffice to say this is an area of improvement in graphite shaft production that needs to be addressed as long as clubmakers and manufacturers desire accurate fitting information about shafts. The advantage this test project had over shafts that clubmakers use "in the field" was the fact the tests were performed with shafts that were hand selected as close to the manufacturers' stated specifications. Therefore, it is the belief of Dynacraft personnel that the graphite shaft test results were reliable. In all likelihood, as graphite-manufacturing techniques improve, competition among the shaft makers will ensure that this aspect of current shaft inconsistency will improve in the future as well.

Deviation in Steel Shaft Frequency within Each Individual Flex

In trying to quantitatively compare the stiffness of the five basic flex levels in the shaft industry today, the test results of all the individual shafts were studied to identify the high-to-low frequency range within each flex and material type. On the following page is a chart of the shafts that represents the low and high frequency readings for each flex within steel shafts.

A quick study of Chart 4-4 of the high-to-low ranges within each of the five flexes of steel shafts shows a tremendous deviation in stiffness within each individual flex level. From the overall test averages of steel shaft frequency (detailed in Charts 4-1), 10 cpm can be considered the difference between two adjacent flexes. With this average in mind and noting the high-to-low deviation within each flex as listed in the right-hand column of Chart 4-4, most of the flexes of steel shafts showed a range of two to three flex levels! The deviation within the X-flex shafts was very low due to the fact that far fewer X-flex steel shafts were tested than were L, R and S-flex shafts.

Chart 4-4 - 1992 Frequency Deviations for Steel Shafts within Each Flex

DRIVERS

Flex	Test Ave.	Low	High	Deviation
L	235 cpm	Gold Plus L3 (215 cpm)	Phoenix L (249 cpm)	34 cpm
A	239 cpm	Dynamic A & Shadow A (233 cpm)	Precision FM4.5 (250 cpm)	17 cpm
R	249 cpm	MatchFlex R (235 cpm)	Orient Standard R (265 cpm)	30 cpm
S	260 cpm	MatchFlex S (250 cpm)	Dynamic Reinforced Tip (276)	26 cpm
X	273 cpm	Dynamic X (272 cpm)	Precision FM7.5 (285 cpm)	13 cpm

#5-IRONS

Flex	Test Ave.	Low	High	Deviation
L	290 cpm	Gold Plus L3 (266 cpm)	Precision FM3.5 (304 cpm)	38 cpm
A	287 cpm	Microtaper A (274 cpm)	Precision FM4.5 (304 cpm)	30 cpm
R	297 cpm	Gold Plus R2 (281 cpm)	Precision FM5.5 (313 cpm)	32 cpm
S	308 cpm	Gold Plus S2 (296 cpm)	Precision FM6.5 (324 cpm)	28 cpm
X	323 cpm	MasterFlex X (323 cpm)	Precision FM7.5 (334 cpm)	11 cpm

L-flex frequency measurements were tested at ladies standard length (42", C-6 Driver, 36.5", C-6 #5-iron)
A-X-flex frequency measurements were tested at men's standard length (43", D-1 Driver, 37.5", D-1 #5-irons)

The significance of this observation represents a tremendously important realization about shaft flex. Most golfers have only the letter code of the flex printed on the shaft label to rely upon when making their shaft selections. Because the same five basic flexes have existed in the game for quite some time, it is probably safe to conclude that virtually all golfers today believe that shaft flexes correspond equally from manufacturer to manufacturer. Ask any golfer if the R-flex in one club exhibits the same stiffness as an R-flex in another club, and he will most likely say it does. Yet, looking at the high-to-low frequency measurements within each individual shaft flex, with deviations of 11 cpm to 38 cpm among shafts that are supposedly the same flex, it is difficult to believe any sort of flex equality or uniformity of stiffness exists within each flex category.

It is very important that clubmakers take this information not as a condemnation of the shaft companies and their quality control procedures, but simply as a lack of standards concerning shaft flex in general. As mentioned earlier when the impetus for this test project was explained, each shaft manufacturer is free to make its own decisions about what the standards for flex will be for all of its various shaft designs. So far, from the analysis of the deflection and the frequency results, it is obvious that variations in stiffness do exist within each of the five basic flexes. What golfers and clubmakers can do about it (or rather, how they can learn to live with it), will be covered later in Chapter 7 when all of the test data is consolidated into more precise fitting recommendations.

Referring back to the comparisons of frequency measurements among the steel shafts, within the L-flexes for Drivers and #5-irons, another interesting discovery was the fact that the True Temper Gold Plus L300 shaft tested out at a very low frequency when compared to the rest of the L-flex shafts. Even more significant is that the highest measured L-flex shafts were actually stiffer than the low end of the S-flex range! Since the 235-cpm Driver average was much closer to the high end of the range, it can be assumed that most of the L-flex shafts possess a frequency closer to the high end of the range. This observation, along with the fact that the L-flex frequencies were, in most cases, higher than the A-flex measurements, again supports the conclusion that almost all L-flex shafts may be too stiff for the average woman golfer.

Continuing with the study of the frequency measurements of the other steel shaft flexes, the high-to-low range in frequency within the steel Driver A-flex level was only 17 cpm, far less than what was found within the R and the S-flex levels. This cannot be considered a significant observation because far fewer A-flex shafts were tested than the number of R and S-flex shafts. However, the same could be said of the A-flex #5-iron frequency averages; yet there was a 30 cpm deviation. Likewise the same type of narrow spread in frequency that was seen in the X-flex steel shafts also was due to a lack of sample test shafts and therefore may not be entirely representative of a true range within the flex.

The real story of significance in the range of frequency in today's steel shafts can be seen after studying the high-to-low range for Drivers in the R and S-flexes. Within the R-flex steel shafts, the range from the Apollo MatchFlex (235 cpm) to the Orient Standard (265 cpm) represents a deviation of 30 cpm, which could be construed to be as much as a span of three full flexes. Within the S-flex steel shafts, the 26-cpm range between the Apollo MatchFlex S (250 cpm) and the True Temper tip-reinforced Dynamic S (276 cpm) demonstrates approximately a 2 1/2 flex difference. All of the R and S-flex Driver shafts were tested at identical length and swingweight, and because a statistically significant number of R and S-flex shafts were tested, this data verifies an important point that has never been fully realized by golfers and clubmakers. From a frequency standpoint, the flexes within all of today's steel shaft designs simply are not uniform.

Perhaps one of the most interesting observations that can be made from studying the high-to-low ranges in frequency within each steel shaft flex was how many times the Brunswick (currently Royal Precision) FM shafts demonstrated the highest frequency for a particular flex. Another shaft of note, the TT Lite, is the most popular steel shaft in all of component clubmaking and without a doubt is the shaft that is most widely selected by clubmakers for the majority of players of average ability. Considering the fact that the TT Lite frequency tested at levels that were 10 cpm greater than the overall test averages for each flex, it would be safe to conclude that the TT Lite may be too stiff for the vast majority of players who currently use the shaft.

Deviations in Frequency within Individual Graphite Flexes

After studying Chart 4-5 of the high-to-low frequency range within each individual flex for graphite shafts, it can be seen an even greater difference exists than for the steel shafts. While the steel shafts showed a 20-30 cpm range from high to low within each flex, the graphite shafts varied in frequency from a low of 25 cpm (A-flex Drivers) to an incredible 78 cpm (X-flex irons), just within the same flex!

Chart 4-5 - 1992 Frequency Deviations for Graphite Shafts within Each Flex

DRIVERS

Flex	Test Avg.	Low	High	Deviation
L	248 cpm	Cosmo Jet (223 cpm)	HM-40 Low Flex L (266 cpm)	43 cpm
A	245 cpm	ACTivator 4.0 A (230 cpm)	Receptor A (255 cpm)	25 cpm
R	255 cpm	Aldila Velocitor R (239 cpm)	Aldila Low Torque R (277 cpm)	38 cpm
S	269 cpm	Aldila Velocitor S (246 cpm)	Aldila Low Torque S (290 cpm)	44 cpm
X	283 cpm	Aldila Velocitor X (246 cpm)	Aldila Low Torque X (309 cpm)	63 cpm

#5 IRONS

Flex	Test Ave.	Low	High	Deviation
L	290 cpm	Kunnan K4 L (269 cpm)	Aldila Low Torque L (302 cpm)	33 cpm
A	277 cpm	System Flex K4SL (255 cpm)	Aldila Low Torque A (294 cpm)	39 cpm
R	291 cpm	Aldila Velocitor R (266 cpm)	Aldila Low Torque R (306 cpm)	40 cpm
S	306 cpm	Aldila Velocitor S (267 cpm)	Apollo HMF Lo Torque (324 cpm)	57 cpm
X	318 cpm	Aldila Velocitor X (269 cpm)	Apollo Boron Tourline X (347)	78 cpm

L-flex frequency measurements were tested at ladies standard length (42", C-6 Driver, 36.5", C-6 #5-iron)
A-X-flex frequency measurements were tested at men's standard length (43", D-1 Driver, 37.5", D-1 #5-irons)

Before absorbing this information and declaring the flex ranges for all graphite shafts to be completely inconsistent, it again has to be understood that the frequency test did not include rotating every shaft four times for frequency averaging. Therefore, it is entirely possible that some of the huge range in graphite shaft frequency from high to low within a particular flex could come from having accidentally tested the stiff side of one shaft or the soft side of another.

Despite this consideration, it is still a fact that graphite shafts do exhibit a wider variation in frequency within single flexes than do steel shafts. Let us focus on the most common flexes; the Regular and the Stiff. Chart 4-5 reveals that the graphite shafts showed a 38 cpm range in the R-flex Driver shafts and a 40 cpm spread within the R-flex #5-irons, and a 44 cpm and 57 cpm range for the S-flex graphite shafts for Drivers and #5-irons, respectively.

The high-to-low ranges in frequency for each flex demonstrates that graphite Driver shafts are stiffer than their steel counterparts while the graphite iron shafts are much closer in frequency to their steel equivalents. In the deflection testing as well, it was shown that the graphite Driver shafts were made to be stiffer than the steel Driver shafts. During the discussion on deflection, this increase in stiffness was likely due to the fact that graphite-shafted clubs required greater head mass to achieve the same swingweight as compared to a steel-shafted club. Therefore, it was theorized that the graphite shafts were made with less deflection so that under the increased bending influence of the greater headweight, the graphite shafts would achieve the same relative stiffness of steel shafts of the same flex.

Since frequency testing is a more dynamic type of flex testing than deflection, should the fact that the frequency tests were performed on finished clubs, with the higher headweight, have made the steel and graphite frequencies the same? The frequency tests did not show this. The testing for both the Driver and #5-iron showed the same relationships to steel flexes as was seen in deflection. Graphite Driver shafts are made stiffer than steel shafts of the same flex, but graphite #5-iron shafts show approximately the same level of stiffness as steel shafts of the same flex.

Before moving on in this discussion, it is important for clubmakers to realize that the much wider frequency range within each individual flex that was demonstrated by the graphite testing cannot be taken as proof of manufacturing inconsistency. While the complete discussion of the role of torque is yet to be covered in this book, it is already accepted that torque does have an effect on the overall stiffness of the shaft. It is possible for the graphite shaft manufacturers to have intentionally designed a greater frequency range into the shafts for each flex because of the anticipated effect of the torque. For example, a higher torque reading for a shaft, such as 5.5º , will have the effect of softening the overall feel of a shaft. Therefore, if a graphite shaft with such a high degree of torque also is made with a higher than normal frequency. When the shaft is played, it may not feel as stiff as the frequency reading alone might indicate.

Because a lower torque reading, such as 2º or less, will have the effect of stiffening the overall feel of the shaft, the opposite statement could be made. Hence, if a graphite shaft with a low torque dimension also possesses a very low frequency for that shaft, the overall feel of the shaft will not be as soft as the frequency measurement alone would indicate. Therefore, with this information in mind, at this stage of the discussion clubmakers are urged to not yet label graphite shafts with particular high or low frequency readings as being too stiff or too soft.

The ability of graphite shaft manufacturers to intentionally vary the frequency and the torque of their shafts has to be looked upon as one of the positive features of composite shaft design ... if the two specifications are matched correctly to the golfer. Just as high torque can soften a high frequency shaft and a low torque can firm up a low frequency, so too can the combination work to the golfer's disadvantage. For example, if a graphite shaft with a high frequency for its flex level is produced with a very low torque dimension, the shaft becomes even stiffer than what the frequency would indicate. Conversely, if a graphite shaft with a low frequency is produced with a high torque dimension, the shaft becomes even softer than what the frequency would indicate. Again, later on in this book, the factor of torque is blended into the overall picture of shaft flex. Clubmakers will be able to gain a much clearer view of just how graphite shafts blend into the flex levels of all shafts.

SHAFT FLEX - A 2000 Comparison of the Frequency Measurements

Since the original version of book was published, eight years have passed and 1500 additional shafts have been tested at Dynacraft's research facility. What changes, if any, have been made by the manufacturers to standardize flexes? How do frequencies of graphite shafts compare to steel shafts today? The answers to these questions and many more will follow.

The 1992 frequency averages were shown for two reasons. First, after 1992, shafts were no longer sent to Apollo to be tested. Thus, deflection measurements were no longer part of our on-going testing project. The Dynacraft tech staff decided that frequency would be our primary means of comparing relative stiffness from shaft-to-shaft because the frequency testing included the additional headweight that was used in the actual assembly of a golf club. We still wanted a means of comparing the original deflection data to frequency data with the same set of test samples for clubmakers to be able to understand the meaningful relationship between the two parameters for flex. Second, we wanted to show trends of current shafts in the industry as shafts and shaft manufacturers come and go. All of the graphite shafts in the original study are no longer available as the life cycle of a graphite shaft is much shorter than their steel counterparts. This study would be better understood if the shafts discussed were shafts that consumers today could associate with. Therefore, the shafts that will be discussed will be only current models that are available at this time of this second publication.

Shaft Frequency Averages for Each Flex

From 1989 to 1992, we had tested the majority of graphite shafts that were on the market. After 1992, the floodgates opened as to the number of graphite shafts and graphite shaft manufacturers that existed. While the 1992 average does encompass quite a few shafts to obtain an industry average, the 2000 average frequency chart should offer a more representative industry average of the most common shafts available in the component market.

Chart 4-6 - 2000 Shaft Frequency Averages by Flex for Steel and Graphite Shafts

Flex	Wood Steel	Graphite	Iron Steel	Iron Graphite
L[1]	234 cpm	237 cpm	285 cpm	276 cpm
A	234 cpm	240 cpm	279 cpm	278 cpm
R	252 cpm	254 cpm	301 cpm	293 cpm
S	264 cpm	267 cpm	316 cpm	307 cpm
X	272 cpm	278 cpm	324 cpm	315 cpm

[1] L-flex measured at ladies standard length for both the wood and iron models.

From comparing Chart 4-6 to Chart 4-1, there are some obvious conclusions that can be made. First and foremost is that the graphite L-flex wood and iron shafts are considerable more flexible than they were eight years ago. The graphite shaft manufacturers must have found that shorter assembly lengths and lighter swingweights required that the raw shafts be made more flexible in order to be useable for whom they where intended. Whether the manufacturers found this out for themselves or through customer feedback, the frequency adjustments now made the L-flex more in-line with the rest of the flexes.

Another observation found is that the average frequency of the steel and graphite Driver shafts were almost identical to one another. The steel averages increased, while at the same time, the graphite averages decreased. Yet, the #5-iron average did not follow this trend. While the R, S and X-flex steel #5-iron shafts increased in average frequency, the men's flex graphite shafts remained relatively unchanged. In 1992, the deviation between steel and graphite #5-iron frequency for each flex produced a random pattern, but in 2000, the graphite shafts are approximately 9 cpm consistently lower than the comparable steel flex, with the exception of the A-flex.

The newly calculated averages do show some encouraging signs by the manufacturers. The average Driver frequencies are now consistent between steel and graphite for each flex. Although the average frequency of graphite #5-irons do not average the same as steel shafts for each flex, at least they are consistently lower. Before you read further, remember average frequencies are the culmination of all the shafts, including the high and low deviations that exist from shaft-to-shaft and manufacturer-to-manufacturer.

Deviation in Steel Shaft Frequency within Each Individual Flex

In the 1992 study, steel shafts did not show that great of a deviation within a given flex as did graphite shafts. With the limited number of steel shaft producers, one would think that the deviation has not changed over the years. Yet, examining Chart 4-7, you will notice an even greater discrepancy in how manufacturers label the flexes of their shafts.

Chart 4-7 - 2000 Frequency Deviations for Steel Shafts within Each Flex

DRIVERS

Flex	Test Ave.	Low	High	Deviation
L	234 cpm	Release w/ SensiCore (230 cpm)	TT Lite L (241 cpm)	11 cpm
A	234 cpm	UCV2000 A (225 cpm)	TT Lite A (239 cpm)	14 cpm
R	252 cpm	UCV2000 R (234 cpm)	Rocket R (281 cpm)	47 cpm
S	264 cpm	UCV2000 S (242 cpm)	Rocket S (295 cpm)	53 cpm
X	272 cpm	Dynamic Gold w/ SensiCore X (259 cpm)	Dynalite Gold X100 (278 cpm)	19 cpm

#5 IRONS

Flex	Test Ave.	Low	High	Deviation
L	285 cpm	Release L (270 cpm)	TT Lite L (298 cpm)	28 cpm
A	279 cpm	UCV2000 A (266 cpm)	TT Lite A (297 cpm)	31 cpm
R	301 cpm	UCV2000 R (277 cpm)	Rocket R (330 cpm)	53 cpm
S	316 cpm	UCV2000 S (285 cpm)	Rocket w/ SensiCore S (342 cpm)	57 cpm
X	324 cpm	Dynamic Gold Lite w/ SensiCore X (307)	Dynamic X (338 cpm)	31 cpm

L-flex frequency measurements were tested at ladies standard length (42", C-6 Driver, 36.5", C-6 #5-iron)
A-X-flex frequency measurements were tested at men's standard length (43", D-1 Driver, 37.5", D-1 #5-irons)

Comparing Chart 4-7 to Chart 4-4 demonstrates just how important it is for accurate shaft information. Instead of the deviation between the high and low spectrum of frequency measurements within a given flex becoming narrower, in many cases it is much wider. If 10 cpm is representative of one full flex, then the difference in the R and S-flex #5-iron shafts spans more than five flex levels, even though the generic letter flex codes are identical!

If we concentrate just on the low end of the range for each flex, there is a very valid reason for the low frequency readings. In each case, the shaft that is listed represents the lightest shaft (or one of the lightest) in each flex designation. By virtue of their lighter weight, there is less material to resist the bending moment of the shaft. Therefore, a cut steel shaft weight in the sub-100 gram range will exhibit a lower frequency reading than shafts that weight considerably more.

In many cases, the same shafts are listed on either the high or low side of the range for both woods and irons. The Royal Precision UCV2000 shafts exhibit far lower readings than any other shafts within the same flex designation, while the Rocket shafts ran considerably higher. If these two shaft patterns were not included in the study, then the deviation in frequency would be considerably lower in the R and S-flexes. On the surface, the problem of flex-to-flex comparison looks dim. Once you dig deeper, the problem, at least in steel shafts, is not as great as long as you can identify the few shafts that don't necessarily reflect the norm.

Looking back at Chart 4-4, Royal Precision FM shafts showed up several times as the stiffest shafts in their respective flexes. In a more recent development, Royal Precision changed their flex designations to coincide with the rest of industry. For example, the 5.5 FCM level for years was described as an R-flex. However, the 5.5 FCM level has now been categorized by the manufacturer as an S-flex.

Deviations in Frequency with Individual Graphite Flexes

Graphite shafts demonstrated a much wider range in frequency than did their steel counterparts. This may be in part due the varying philosophies of so many more graphite shaft producers or the combination of materials allow for the greater latitude of altering the designs of their shafts.

Chart 4-8 - 2000 Frequency Deviations for Graphite Shafts within Each Flex

DRIVERS

Flex	Test Ave.	Low	High	Deviation
L	237 cpm	Phoenixx ThermoLite L (220 cpm)	Dynacraft Dynatech L (254 cpm)	34 cpm
A	240 cpm	Graman Super Flex 310A (219 cpm)	Dynacraft Dynatech A (257 cpm)	38 cpm
R	254 cpm	Jordan Thermoplastic R (216 cpm)	Rapport Synsor R (277 cpm)	61 cpm
S	267 cpm	Jordan Thermoplastic S (235 cpm)	System Flex KF1 Ultralight S (295)	60 cpm
X	278 cpm	Phoenix P-series 1250 (261 cpm)	Rapport Hyperflex Tour X (308)	47 cpm

#5 IRONS

Flex	Test Ave.	Low	High	Deviation
L	276 cpm	Aldila UL L (247 cpm)	Grafalloy Lady Classic L (302)	55 cpm
A	278 cpm	TT Lite XL Graphite A (252 cpm)	Dynacraft Dynatech A (291 cpm)	39 cpm
R	293 cpm	Aldila LW R (261 cpm)	Rapport Hyperflex Tour R (315)	54 cpm
S	307 cpm	SensiCore Graphite Tour Flight S (279 cpm)	Paragon Low Torque (331 cpm)	52 cpm
X	315 cpm	Aldila SW taper X (293 cpm)	Rapport Hyperflex Tour X (332)	39 cpm

L-flex frequency measurements were tested at ladies standard length (42", C-6 Driver, 36.5", C-6 #5-iron)
A-X-flex frequency measurements were tested at men's standard length (43", D-1 Driver, 37.5", D-1 #5-irons)

Chart 4-8 reveals there is still a huge range of frequency amongst graphite shafts with the same flex designation, as much as 60 cpm. In addition, there are still cases where an L-flex shaft has a higher frequency reading than an X-flex shaft. There has been a recent trend in the shaft industry to lessen the stiffness of graphite shafts. Most of the shafts on the high end of the range are older shafts that have not been phased out by the manufacturer or redesigned to decrease the stiffness.

One interesting note is the majority of the lowest recorded Driver shafts are manufactured, not of graphite, but of a thermoplastic material. Both Phoenixx and little known Jordan, state the material used in their shafts perform dynamically stiffer than how they are measured. Thus, this may be a reason the both manufacturers designed the shafts as flexible as they are measured.

Comparison of Ultra-lightweight Graphite Wood Shafts

When the Dynacraft/Apollo shaft-testing project started, there were only a few ultra-lightweight (sub-70 grams) available. Each of this limited number of shafts was designed specifically for lady or senior golfers. In the mid-1990's, an assortment of ultra-lightweight graphite shafts were designed for stronger golfers and were manufactured with specialized materials that could withstand breakage and be made stiff enough for the most powerful golfers in the world. This timing coincided with the newest material made for woods - titanium. Manufacturers built the titanium Drivers at longer-than-normal lengths in order to achieve the benefit of the lighter weight club. No longer was the standard length 43", as at the time of our initial testing project; the ultra-lightweight shafts were designed to be assembly at 45" or longer for Drivers.

To test the ultra-lightweight shafts, it became apparent that we needed to test the shafts at the lengths they were intended for - 45". Chart 4-9 is the average frequency for the ultra-light graphite shafts as a means of comparing standard graphite shafts.

Chart 4-9 - 2000 Frequency Averages by Flex for Ultra-lightweight Graphite Driver shafts

Flex	Average Frequency
L	221 cpm
A	230 cpm
R	241 cpm
S	257 cpm
X	262 cpm

L-flex frequency measurements were tested at 44" and C-6 swingweight.
A-X-flex frequency measurements were tested at 45" and D-1 swingweight.

Comparing Chart 4-9 to Chart 4-6, the average frequency of an ultra-lightweight shaft is between 10 and 16 cpm lower than standard weight graphite within the same flex designation. Does this mean that the ultra-lightweight graphite shafts are more flexible than heavier weight graphite? This is not necessarily correct. Just as described in the Chapter 3 regarding deflection, two frequency measurements to be accurately compared, must be tested at the same length. As the shaft becomes longer, the deflection was greater for the same shaft. Therefore, the longer ultra-lightweight shaft should also be more flexible, or possess a lower frequency measurement as well. We will go more in depth regarding length in Chapter 7 of this book.

Comparison of Frequency between Individual Steel Shaft Patterns

Ultimately, one of the comparisons that clubmakers will want to make is between individual shaft patterns of the same flex. How does a Dynamic S correspond to a Precision Rifle 6.5 or a TT Lite R to a Shadow R? The comparisons could go on and on due to the vast number of different shafts available today. But until now, such comparisons have been quite impossible to make due to a lack of comparable information.

To this point in this chapter we have identified the average frequencies for each of the various flexes in the golf shaft industry, as well as the deviations that exist between each of the five basic flex levels. These observations are important to show the variation in flex that exists within the shaft industry - a variation that becomes even more critical as we move the discussion toward individual shaft comparisons. Following are Charts 4-10 and 4-11 which contain frequency measurements of Drivers and #5-irons for many of the industry's popular parallel tip steel shaft patterns. After the discussion of these steel shaft frequencies, similar charts with regard to graphite wood and iron shaft frequencies will be presented.

The charts of steel shaft frequency measurements for Drivers and #5-irons are somewhat extensive and as such, will require a bit of study before moving into a discussion of frequency between different shaft patterns. For a full list of all the steel shaft frequency measurements, please refer to the accompanying addendum of test data. To afford a measure of comparison, each of the charts is headed by the overall frequency averages of each flex for all of the steel shafts that were tested in the entire project. In addition, an average frequency for the steel shafts made by each manufacturer was calculated from the test shafts. Consequently, each shaft that is included in the chart can be compared not just to other steel shafts, but to the test averages as well for the purpose of better understanding how any particular shaft may rank in frequency.

Chart 4-10 - Driver Frequency Measurements for Parallel Tip Steel Shafts

Shaft	L-flex	A-flex	R-flex	S-flex	X-flex
Test Averages					
Steel Shafts	234	234	252	264	272
Apollo					
Acculite	N/A	N/A	253	263	N/A
AP44	N/A	N/A	247	259	N/A
Balistik	N/A	244	255	265	N/A
MasterFlex	N/A	N/A	254	265	274
MatchFlex	N/A	N/A	250	269	N/A
Platinum	N/A	N/A	247	256	N/A
Shadow	233	232	252	264	N/A
Spectre	239	239	251	262	N/A
Average	**235**	**235**	**251**	**263**	**274**
Royal Precision					
Microtaper	240	238	247	260	N/A
Rifle	N/A	N/A	247	266	274
Rifle Lite	N/A	N/A	N/A	268	277
UCV2000	230	225	234	242	N/A
Average	**235**	**232**	**243**	**259**	**276**
True Temper					
Dynalite	233	232	256	265	N/A
Dynalite Gold	N/A	N/A	258	266	278
Dynamic	235	233	250	261	272
Dynamic Gold	N/A	N/A	248 (R200)	259 (S200)	269 (X100)
Dynamic Gold	N/A	N/A	249 (R300)	261 (S300)	N/A
Dynamic Gold	N/A	N/A	250 (R400)	262 (S400)	N/A
Dynamic Gold SensiCore	N/A	N/A	241	252	259
Extralite	N/A	N/A	257	271	273
Release	232	234	N/A	N/A	N/A
Rocket	N/A	N/A	281	295	N/A
TT Lite	241	239	244	258	N/A
Average	**235**	**235**	**253**	**265**	**270**

L-flex frequency measurements were tested at ladies standard length (42", C-6 Driver)
A-X-flex frequency measurements were tested at men's standard length (43", D-1 Driver)
N/A indicates that the shaft was not tested or it was not simply available in that pattern.

Chart 4-11 - #5-iron Frequency Measurements for Parallel Tip Steel Shafts

Shaft	L-flex	A-flex	R-flex	S-flex	X-flex
Test Averages					
Steel Shafts	285	279	301	316	324
Apollo					
Acculite	N/A	N/A	311	328	N/A
AP44	N/A	N/A	301	314	N/A
Balistik	N/A	294	307	317	N/A
MasterFlex	N/A	N/A	305	318	323
MatchFlex	N/A	N/A	302	320	N/A
Platinum	N/A	N/A	305	320	N/A
Shadow	289	280	298	303	N/A
Spectre	300	295	299	306	N/A
Average	**295**	**290**	**304**	**316**	**323**
Royal Precision					
Microtaper	282	274	287	298	N/A
Rifle	N/A	N/A	307	319	328
Rifle Lite	N/A	N/A	N/A	322	330
Rifle Weight Series	N/A	N/A	292	318	N/A
UCV2000	275	266	277	285	N/A
Average	**279**	**270**	**291**	**308**	**329**
True Temper					
Dynalite	290	290	304	317	N/A
Dynalite Gold	N/A	N/A	298	308	322
Dynamic	281	278	310	323	338
Dynamic Gold	N/A	N/A	302 (R200)	318 (S200)	329 (X100)
Dynamic Gold	N/A	N/A	304 (R300)	320 (S300)	N/A
Dynamic Gold	N/A	N/A	307 (R400)	322 (S400)	N/A
Dynamic Gold SensiCore	N/A	N/A	303	319	329
Dynamic Gold Lite	N/A	N/A	282	294	308
Extralite	N/A	N/A	304	318	324
Gold Plus SensiCore	N/A	N/A	292	305	N/A
Release	270	275	N/A	N/A	N/A
Rocket	N/A	N/A	330	341	N/A
Tri Gold	N/A	N/A	293	302	N/A
TT Lite	298	297	315	325	N/A
Average	**285**	**285**	**303**	**316**	**325**

L-flex frequency measurements were tested at ladies standard length (36.5", C-6 #5-iron)
A-X-flex frequency measurements were tested at men's standard length (37.5", D-1 #5-irons)
N/A indicates that the shaft was not tested or it was not simply available in that pattern.

Both Chart 4-10 and 4-11 have been set up to show the frequency measurements of the golf industry's most popular steel shaft patterns for assembled Drivers and #5-irons. It is interesting to note that within the same manufacturer, you can see a wide deviation between shafts of the same flex. For example, within the R-flex Drivers, of True Temper's line of steel shafts, the frequency measurements range from a low of 241 cpm (Dynamic Gold with SensiCore R300) to a high of 281 cpm (Rocket). Among True Temper's different steel designs, this 40 cpm deviation could be viewed as being significant in light of the 10 cpm average which separates the individual flexes of steel shafts.

Looking at True Temper's line, it is important to notice the difference between Dynalite and Dynalite Gold shafts. In the wood version, the frequencies are very comparable, but the irons are strikingly different. For years, many clubmakers knew the biggest difference between Dynamic and Dynamic Gold was that the Gold series was weight sorted, because when you set them side-by-side, they are identical. When Dynalite Gold debuted, clubmakers assumed that the Dynalite Gold was just a weight-sorted version of Dynalite. However, when the Dynalite Gold iron shafts were designed, an extra 1" was added to the tip to first step dimension.

Over the years, the manufacturers have changed certain shaft patterns. The Apollo MatchFlex had been re-engineered and now possesses a higher frequency than the older version (1989-90) that was included in the original test group of shafts. As a result, if the 235 cpm R-flex and the 250 cpm S-flex measurements for the older MatchFlex are discarded, Apollo's steel Driver shafts also display a relatively close range within each flex, nearly parallel to that of True Temper.

Should a shaft manufacturer design all of its steel shafts to have the same frequency within each individual flex? This may be a point of debate that is far too subjective to try and pinpoint an answer. After all, just as each shaft company is free to set up its own standards of stiffness for each particular flex, so too are they free to design the flexibility of each different pattern in an effort to appeal to all sorts of different player types. Should the frequency of an R-flex Dynalite Gold be the same as the frequency of an R-flex Dynamic Gold shaft? Since the pattern characteristics of the Dynamic Gold (standard weight, tip firm, high bend point) are aimed at the player with better swing fundamentals, True Temper or any shaft maker is free to exercise the belief that maybe the individual flexes for this more accomplished type of golfer should display a higher frequency.

In the end, considering the fact that the shaft patterns made by each shaft manufacturer are designed to be different in playability. It stands to reason that there would be slight differences in frequency within the same flex level, due to the changes in the other shaft parameters such as weight, bend point and/or balance point, that are required to make the different types of shaft designs.

Frequency Comparison between Different Shaft Manufacturers

It has just been established that in comparison to the overall high-to-low ranges of frequency within each of the flexes, there exists a reasonably narrow range among the common and popular steel shafts offered by each steel shaft producer. But what about frequency comparisons between the different steel shaft manufacturers? Do the various flexes of steel shafts display a uniform frequency, and therefore, comparable flexibility?

After calculating the average frequency for each steel shaft flex, for each manufacturer, it is fascinating to see that approximate standards for flex, as defined by frequency, do seem to exist to a certain extent within steel shafts. Study the comparison that follows in Chart 4-12 and note the comment below the chart about the skewing effect that exists within the Royal Precision shafts.

Chart 4-12 - Comparison of Average Frequency Measurements by Manufacturer

Manufacturer	L-flex	A-flex	R-flex	S-flex	X-flex
Driver Frequency Averages					
Apollo	235	235	251	263	274
Royal Precision	235	232	243	259	276
True Temper	235	235	253	265	270
#5-iron Frequency Averages					
Apollo	295	290	304	316	323
Royal Precision	279	270	291	308	329
True Temper	285	285	303	316	325

If frequency can be accepted as one type of a quantitative measurement of flex, from this chart it could be said that the steel shafts made by the three major steel manufacturers do fall within a narrow, consistent range for each flex level. Only Royal Precision averaged slightly lower than the other two steel producers, partly due to a few factors. First, with the limited number of shafts tested, the low readings of the UCV2000 skewed the results. The other factor is the L, A and R-flexes are not represented well enough to provide a valid average for what Royal Precision produces. At some point in the future, the lower flexes of the Rifle family will be tested. Still, a very key point in this discussion is the fact that golfers do not play with averages; they play with individual shafts.

The overall frequency testing segment of the Dynacraft/Apollo shaft testing project has been able to identify averages for each flex and show that the average frequencies of patterns made by the major steel shaft manufacturers do come very close to the overall test averages. Yet it is only logical that they should, because the shafts from the three major manufacturers make up the majority of the patterns used to calculate the overall test averages for steel shafts! Such a point is no great revelation. What is important is the fact that the individual shafts vary up and down from these industry frequency averages, underscoring a key discovery of this research - that complete uniformity of frequency among all the different patterns of steel shafts just does not exist.

Comparison of Frequency between Individual Graphite/Composite Shafts

To extend the discussion of frequency as a means of comparing the flex of graphite shafts, the following section will include an analysis of the frequency measurements of a number of the industry's composite shafts. Over the past decade, the methods of designing and producing graphite shafts have undergone a state of almost continual change in an effort to produce lighter, stronger and more accurately made shafts. Because of the fast growing popularity of graphite shafts, and the fact that a new composite design can be brought from drawing board to production much faster than a new steel shaft, every year many new graphite/composite shafts are being introduced. Yet despite the fact graphite shafts are manufactured through an entirely different process than steel shafts, they still must ultimately be compared to steel shafts so that golfers and clubmakers can make accurate recommendations for their use.

Stretching and reducing steel alloy tubes produces steel shafts. From welding to drawing to heat treating to electroplating, every single aspect of their manufacture is geared to their metallic makeup. Winding or wrapping fiber/epoxy materials around a forming rod or mandrel, after which they are squeezed around the mandrel in an effort to compress the layers tightly together, produces Graphite/composite shafts. From preparing the fiber material to wrapping to compressing to baking to painting, every aspect of their manufacture couldn't be more different from the production methods of steel shafts. Because there are many golfers who play with both types of shafts in their one set of golf clubs, it is a very important goal of this shaft testing project to be able to relate and compare the different designs of steel and graphite shafts.

Given the incredible amount of time that is required to obtain accurate shaft measurements for this test project, it just is not possible to include all of the very latest graphite shaft models in the full body of the test information. However, every effort has been made to include as many of the industry's most recent and most popular models of graphite shafts within the two aspects of the test which will be most heavily used for making fitting recommendations, frequency and torque.

Before studying the frequency data that is offered in Chapter 4 in the accompanying addendum, clubmakers once more must realize that frequency alone cannot be used solely to gauge the comparative stiffness of graphite shafts. Unlike graphite, it is far more appropriate to use frequency measurements to make relative stiffness comparisons between steel shafts. This is largely due to the fact that, for the most part, torque measurements of steel shafts do not vary as they do in graphite designs.

Even before the Dynacraft/Apollo shaft testing project was started; many clubmakers began to suspect that torque definitely had an effect on the overall stiffness feel of a graphite shaft. Among steel shafts, in which the torque from one steel shaft to the next varies by little less as 1º, frequency comparisons can deliver a very good sense of relative stiffness feel. In other words, if the frequency of one steel shaft is 20 cpm greater than another steel shaft, it is very safe to say that the shaft with the much higher frequency will feel and play stiffer.

In graphite shafts this will never be the case. Because torque does vary by design from shaft to shaft, torque eventually must be added to the overall evaluation of stiffness feel. In today's graphite/composite shafts, the torque can range from less than 2º up to more than 9º. Therefore, the torque that is virtually a constant in steel shafts now becomes an additional variable in trying to gauge the final, overall relative stiffness of graphite shafts. Later in this book, as torque is integrated into the discussion of flexibility, a much clearer picture of graphite shaft fitting will be presented. Therefore, clubmakers are urged not to use the following frequency data solely to make definitive shaft to shaft flex fitting comparisons between graphite shafts.

Early in this chapter a comparison was made which identified the high-to-low ranges in frequency for each flex, first for steel and then for the graphite shafts (Charts 4-7 and 4-8). While the comparison did show that shafts within all of the five basic flexes (L, A, R, S, X) do vary in frequency from manufacturer to manufacturer, the high-to-low variation within each of the individual flexes of graphite shafts is much greater than it is in steel shafts. Part of this difference can be explained by the fact that the frequency of graphite shafts may be designed with the torque in mind.

This frequency variation among the graphite shafts within the same flex is not entirely a matter of inaccuracy. It is a matter of designing shafts that take into account what effect the increased headweight and the torque are going to have on the overall flex feel of the shaft. Unlike steel, graphite shaft manufacturers have the ability to intentionally alter frequency and torque in the production of their shafts. By selecting fiber material of different strengths and by changing the orientation of the fibers to the axis of the shaft, stiffness and torque can be made to virtually any specification the designer wants. Therefore, when a particular torque value is selected for the design, many times the frequency will intentionally be changed one way or another to accommodate the torque in order to make the shaft play with a certain stiffness feel. As a result, a graphite shaft with a frequency 20 cpm higher than other shafts of the same flex may be produced that way by intent and not be a result of inaccuracies, especially if the shaft also possesses a torque rating higher than what is common for steel shafts. To better explain, the company may have designed the frequency to be much higher to allow for the flex softening effect of the higher torque, along with the flex softening effect of the higher headweight when the shaft is assembled into a finished golf club.

Unlike graphite, steel shaft manufacturers can only effect a distinct change in the design of the stiffness (frequency and deflection) of their shafts. The torque of a steel shaft is controlled by the shaft's diameter profile, weight, and the stiffness of the design, and cannot be created independent of the frequency or flex. In other words, if a steel shaft maker and a graphite shaft maker both design a shaft with the same frequency, at this point the torque of the steel shaft cannot be changed by more than a fraction of a degree. But in the graphite shaft, once the frequency is set, the designer can still significantly alter the torque, just by changing the material make-up and the fiber orientation of the materials within the shaft.

The greater high-to-low range in graphite/composite shaft frequency must be viewed initially as an attempt on behalf of graphite shaft manufacturers to try to create shaft patterns which can cover a much wider range of player types than steel shafts. To explain, the steel and graphite Driver shafts of all the flexes in the test fell in an overall frequency range from 180 cpm up to 309 cpm when tested at ladies and men's standard playing lengths at swingweights of C6 (ladies lengths) and D1 (men's lengths). But all of the steel Driver shafts are only made in a torque range of from 2.5-3.5º, while the graphite/composite Driver shafts will range in torque from 1.7º up to nearly 14º. Since it is now accepted that torque does have some influence on the stiffness feel of shafts, it is fair to say when the effects of frequency and torque are combined together graphite shafts can likely fit a wider range of golfers than steel shafts. Proof of this fact will be seen later in the book in Chapter 7 when torque is mathematically combined with frequency to determine an overall stiffness index. Fitting recommendations from that index will be expressed in clubhead speeds that can be matched with each combination of torque and frequency.

This discussion explains one of the possible reasons graphite shafts exhibits a greater high-to-low range in frequency over steel shafts. However, one other point that quickly becomes apparent after studying the chart of different graphite shaft frequencies is that in the Drivers (and likewise in all the shafts for woods), the frequencies are generally higher than are the Driver frequencies for the same flex in steel shafts. Following is Chart 4-13, which once more illustrates the average difference in frequency between the steel and graphite Driver shafts from the test for each of the primary flexes.

Chart 4-13 - Average Driver Frequency by Flex for Steel and Graphite Shafts

Shaft Type	L-flex	A-flex	R-flex	S-flex	X-flex
Steel	234	234	252	264	272
Graphite	237	240	254	267	278

L-flex frequency measurements were tested at ladies standard length (42", C-6 Driver)
A-X-flex frequency measurements were tested at men's standard length (43", D-1 Driver)

Through all the primary flexes, the average frequency of graphite Driver shafts was greater than steel by approximately 2-6 cpm. However, this same comparison in 1992, yielded a 6-12 cpm deviation. Part of the reason for this increase in graphite Driver shaft frequency over steel again may be related to the ability of the composite shaft makers to change the torque in their designs, in an intentional effort to join torque with the frequency and create a specific flex feel. While not always the case, some of the higher frequency graphite shafts do have a slightly higher torque rating than steel shafts of the same flex level. Therefore, as was mentioned before, the higher frequency could be an intentional specification that helps to offset the stiffness-softening characteristic of the higher torque.

The other reason that most graphite Driver shafts show a higher frequency than steel Driver shafts probably is related to the fact that graphite-shafted Drivers require more headweight to achieve the same swingweight as steel-shafted Drivers. It is a fact that between two Drivers of equal length and the same swingweight, the clubhead on the graphite shaft will weigh more than the head on the steel shaft. Under the speed and force of the swing, it is known that a heavier head will exert more of a bending influence, or flex softening influence, on the shaft. Therefore, the fact that the tests showed graphite Driver shafts to have a higher frequency (as well as a higher deflection as proven from the test results presented in Chapter 3) has to indicate that the graphite shafts also are made stiffer to counteract the effect of the greater headweight.

Iron Shaft Frequency - Graphite vs. Steel

If the graphite shafts for woods are made stiffer than steel shafts of the same flex, then why aren't the graphite iron shafts stiffer as well? In Chapter 3 it was shown that the deflection measurements of graphite iron shafts were virtually the same as steel iron shafts, indicating at least from a deflection standpoint, that the two types of shafts are similar in stiffness. And, just as was discovered from the results of the deflection testing, the frequency test results showed the frequency measurements of virtually all the graphite iron shafts to either be the same or even slightly lower than the steel shafts. Chart 4-14 lists the overall test averages for frequency of the #5-iron steel and graphite shafts for each primary flex.

Chart 4-14 - Average #5-iron Frequency by Flex for Steel and Graphite Shafts

Shaft Type	L-flex	A-flex	R-flex	S-flex	X-flex
Steel	285	279	301	316	324
Graphite	276	278	293	307	315

L-flex frequency measurements were tested at ladies standard length (36.5", C-6 #5-iron)
A-X-flex frequency measurements were tested at men's standard length (37.5", D-1 #5-irons)

Could the information in Chart 4-14 be one of the major reasons why graphite iron shafts have not caught on in popularity like the graphite wood shafts? Add the fact that graphite-shafted irons have a higher headweight than steel-shafted irons of the same swingweight and an additional reason can be seen why graphite-shafted irons probably feel softer in flex. There is no doubt the cost associated with making a switch to graphite in the irons has to be at least one of the reasons; after all, the cost of eight or nine graphite shafts is hard to absorb for many golfers. But what about the professionals, the game's best players who through endorsement contracts do not have to pay for their equipment? Is the disproportionate relative stiffness of graphite iron shafts to the graphite wood shafts a major reason that the tournament professionals have not yet begun to switch to graphite in their irons?

Many graphite shafts are designed to be trimmed from the butt end only, due to a shorter parallel tip section. The larger diameter is always the stiffest end of a shaft. As such, when only butt trimming is performed, the stiffest portion of the shaft is removed and while the shaft does increase in stiffness, its increase is very slight, as it becomes shorter. On the other hand, when tip trimming is performed, the trimming has the effect of removing a portion of the weakest part of the shaft. Therefore, the shaft will increase more in both of the relative stiffness parameters of deflection and frequency.

Steel iron shafts are almost all tip trimmed to provide a frequency slope, while many all-butt trimmed graphite shafts yield a much flatter frequency slope. If we had conducted testing on the #1, 5 and 9-irons, then the average frequency range would show some surprisingly results. The #1-iron shaft averages would show the graphite would be as stiff, if not slightly stiffer on average than steel shafted #1-irons. The #9-iron shaft averages between graphite and steel iron shafts would represent an even wider deviation than the #5-iron testing proved.

Frequency Comparison of Specialty Shafts

As mentioned in Chapter 1 regarding history, an entirely different group of shafts has surfaced which are made from materials or combinations of materials other than steel and graphite. Currently there are, or have been, shafts made from exotic non-ferrous metallic alloys, fibrous materials wrapped over a metallic core, and a host of shafts made from non-graphite fiber materials. During the Dynacraft/Apollo project, to gain more insight into the relationship of these shafts to the all-steel or all-graphite shafts, samples of a number of Ti Shaft, Alloy 2000, Fiberspeed, Easton, Quadrax and Jordan shafts were included in the testing.

Evaluating and comparing the frequency of some of the specialty shafts to the host of steel and graphite shafts can be a bit confusing. Due to the nature of some of the materials used in the manufacture of non-ferrous metallic shafts such as the Ti Shaft designs, the frequency measurements will react somewhat differently than might be expected.

One of the factors, which definitely affect the vibrational frequency of a shaft, is the elasticity of the material from which the shaft is created. The modulus of elasticity for titanium is approximately half of that for steel. As a result, whenever any static type of flex test is performed on the Ti Shaft products, the results will show the shaft to be more flexible on a deflection board and lower on a frequency reading than steel shafts of the same relative stiffness. Therefore, because a frequency test is not exactly the same thing as a golfer hitting the ball, the frequency of titanium shafts will be different for each flex than steel or graphite.

To accept the test frequencies for each flex of titanium shafts at face value would lead to the erroneous assumption that the shafts are much softer in flex than steel or graphite shafts. Due to the very different elasticity of the material, the frequency readings for each titanium flex can be considered to be at least 10 cpm lower than equivalent flexes of a material such as steel. Therefore, it is very important for clubmakers using the information in this test not make direct frequency comparisons between titanium and other material shafts for the purpose of judging differences in flex. Later in the book when the other flex affecting factors are integrated together into a singular judgment of the flex feel of each shaft, the elasticity differences for each shaft will be taken into account.

Unlike the titanium shafts, the now-defunct Alloy 2000 shafts were made from a different non-ferrous metal that does not elicit an effect which can "trick" the comparability of the frequency measuring test. While containing some 12 different materials, the primary metal used in the manufacture of the Alloy 2000 shaft is aluminum. Known for its dampening characteristics, the comparatively low frequency readings for each flex of the Alloy 2000 shaft can be considered to be characteristic of the flex feel of the shaft. As a result, the Alloy 2000 did tend to rate out as more flexible than the overall steel average for each flex in the test.

The Fiberspeed family of shafts was similar to titanium in its characteristic of reacting lower in frequency than what actually happens in play. Produced from high-strength S2 glass fibers, the FS Series of Fiberspeed shafts (FS100, 200, 300) are known for their incredibly flexible feel upon "waggling" or bending by hand. Again, due to the very unique nature of the design and the unusual characteristics of the glass material, the FS series of the Fiberspeed shafts display very, very low frequency readings even at the company's recommended lower swingweight assembly guidelines. For example, the 180 cpm frequency for the FS100 shaft was very difficult to accurately obtain due to the extreme static flexibility of the shaft and problems in getting the shaft to oscillate between the pick-off sensors of the frequency machine.

While the Fiberspeed shafts were very flexible in terms of pure static flex testing, due to the nature of the material and the way in which it is manufactured into the shafts, during a golf swing the manufacturer insists the shafts do not play as flexible as perceived. Again, while allowances will be made when later integrating all of the flex affecting factors together into a fitting recommendation, for now clubmakers are urged not to rely only on pure frequency comparisons between the FS Series shafts and other types of composite material shafts.

Within the Fiberspeed family of shaft designs is also a pattern in which the two flex varieties were named the TP4000 and TP4000+. While also manufactured through one of the Fiberspeed company's patented processes, the TP4000 shafts were made to be substantially stiffer in static flex measurement than the unique FS shafts. Again, as with all of the shafts made from different materials, the unique elasticity characteristics of the respective materials will be taken into account later in the book when calculations are made to evaluate the type of golfer with which the shafts should be matched.

Along the same lines as the Fiberspeed shafts, thermoplastic shafts had similar characteristics. As mentioned earlier, the two companies who produce thermoplastic shafts (Phoenixx and Jordan) had very low frequency readings. Both companies state that the material used in their shaft play dynamically stiffer than measured.

Conclusions about Shaft Frequency Testing

One of the most important discoveries from the frequency testing phase of this project was how much variation exists within shafts of the same industry flex designation. While frequency should not be used as the only means of comparing flex, the simple fact that the frequency testing did show differences between different flexes has to be proof enough that the information can be relied upon to make some comparative conclusions. Granted, a difference of 2-5 cpm between two shafts may not be enough for most golfers to feel a difference in stiffness, but a difference of 20 cpm or more, especially within steel shafts, must be considered a significant deviation.

Whether you are a clubmaker or simply enjoy playing the game, you probably have had the opportunity to hit two clubs labeled with the same flex designation, and found them to be completely different in stiffness feel. The deviations in frequency that exist within various shaft designs of supposedly the same flex designation begin to provide reasoning for these phenomena. In this chapter, many charts of comparative frequency data have been offered to illustrate the variations that are present within shafts of the same flex. While the information is certainly demonstrated in the charts, after so many lists of numbers, the data itself can become confusing. Golfers and clubmakers are more accustomed to relating to shafts by the various designations of L, A, R, S or X-flex. The charts comparing the frequency of steel and graphite shafts and may be the best way to drive home the point that wide variations in flex (as defined by frequency) does exist in shafts today. Therein lies one reason for the some of the guesswork that has been associated with fitting shafts.

Flex and flex feel are completely different factors when it comes to deciding what particular shaft is right for a golfer. As mentioned in this chapter, flex is only stiffness; flex feel or flex playability incorporates all of the flex-affecting specifications such as torque and kick point together. Therefore, frequency alone cannot be used to make fitting recommendations because it does not yet take the other flex affecting shaft specifications into account.

But can frequency be used at all to make accurate flex only comparisons between shafts? In a situation where torque, the primary flex influencing factor other than flex itself, is virtually equal between two shafts, frequency can be used to make a reasonably accurate flex comparison. Because the torque of all the steel shafts included in the test project varied by little more than 1º, it is possible to compare the frequency of two steel shafts and say with reliability the one with the lower frequency is less stiff.

But in the case of graphite or the specialty types of shafts, pure frequency comparisons for the purpose of determining which shaft is stiffer are much more difficult to make. Remember two key points about composite shaft frequency that was developed in this chapter. Clubhead weight on a graphite shaft is usually greater than on a steel shaft, and graphite shaft torque measurements do cover a wider range than steel, pure frequency comparisons for the purpose of judging differences in outright stiffness between graphite shafts and any other type of shaft cannot be made. Once more, and in such a discussion it cannot be said too many times, torque and headweight do affect the final flex feel of a shaft from the standpoint of the golfer. Therefore, because headweight and torque are more variable features in graphite/composite shafts than they are with steel shafts, a greater design range in frequency among the graphite shafts of each flex level will occur.

Even with such a caution, the results of the frequency testing show many very significant discoveries about shafts in general. Among all the shafts tested, each flex level included shafts, which displayed a very wide range in frequency from high to low. While other factors do affect the flex feel of shafts, the range in frequency within each flex level was wide enough to show that no real flex standardization exists within the shaft industry today. While each shaft manufacturer is free to develop its own standards for flex, it is not entirely fair that the golfing public has not been made aware of this practice.

The fact that virtually all L-flex shafts do not fall in a logical sequence of frequency to the other flexes is another important discovery, thus indicating the L-Flex shafts may be too stiff for the average lady player. In addition, realizations about certain individual shaft patterns proved to be interesting. For example, the TT Lite steel shafts were shown as being among the stiffest of all the steel shafts tested within most of the flex levels, while the Dynamic Gold shafts do not display the amount of stiffness increase expected through their sub-flex levels. The concept of flex overlap that has led clubmakers to believe the R400 sub-flex has the same stiffness as the S200 was disproved.

From a graphite shaft standpoint, many of the conclusions have to be carefully tempered by the fact that graphite shafts are entirely different than steel shafts. Still it was interesting to discover that the graphite shafts for woods are almost all made to be more stiff from a frequency standpoint than the same flexes in steel, while the graphite iron shafts and steel iron shafts of the same flex appear to be less stiff. Overall, it was seen that graphite shafts have a wider range in frequency within each flex than steel shafts, but at the same time, a range that is not as condemning as first might be thought due to the fact that torque will have an effect on stiffness. Still, even with the initial statement that graphite shaft manufacturers will change frequency to allow for the effect of torque, the ranges in frequency for graphite within each individual flex are great enough to show that just as with steel, no real flex standardization exists!

A Final Word about the Relationship of Deflection and Frequency

In the test project, two different methods were used to try to obtain a clearer picture about shaft flex. In Chapter 3, deflection as a purely static measurement of flex was discussed, and in Chapter 4, frequency was added as a slightly more dynamic determination. Although later in the book frequency will be used more heavily in the calculation of the fitting guidelines for each shaft, at this point can a correlation be made between deflection and frequency; the industry's two traditional indicators of shaft flex?

Chart 4-15 reveals three shafts, which exhibit the same deflection and frequency, Aldila's Alda VIII L-flex, the Comp50 R-flex from Kunnan and the Alloy 2000 X-flex, all built to men's standard length and swingweight. Do the three shafts play the same?

Chart 4-15 - Driver Test Shafts with Similar Deflection and Frequency

Shaft	Flex	Frequency	Deflection	Headweight	Swingweight/ Club Length
Alda VIII	L	254 cpm	4.88"	216.8 g	D1 / 43"
Alloy 2000	X	255 cpm	4.85"	204.4 g	D1 / 43"
Comp50	R	253 cpm	4.84"	212.0 g	D1 / 43"

Referring to each company's recommendations for their respective shafts, Aldila wrote that the Alda VIII shaft, "... was especially popular with the ladies and senior players." Kunnan said "the Comp50 is the best shaft selection for the professional and top amateur," while the Alloy 2000 shaft was used by PGA Tour professional Phil Blackburn to win successive MCI Long Distance Driving Championships.

These three shafts with the same deflection and frequency creates an interesting situation of comparison - a ladies graphite shaft, another graphite recommended for accomplished players, and a metallic alloy shaft that was used successfully by a tournament professional. Three shafts with identical deflection and frequency parameters yet designed for use by entirely different types of players.

These three shafts were selected from the previous charts for a very important reason, to prove that flex alone, no matter how accurately it can be compared, cannot be used for making pure fitting decisions. Looking further into the comparison, according to each company's literature, the Alda VIII and the Alloy 2000 shafts both have a low kick point, while the Comp50 has a high kick point. Using kick point as a further means of elimination, this would lead to the conclusion that since the Alloy 2000 X-flex and the Alda VIII L-flex have the same deflection, frequency and kick point, when built to the same length and swingweight they are the same shaft... right?

By bringing in one other shaft design parameter that has yet to be discussed - torque - and examining the recommended swingweights for the respective shafts, the real answer to whether the Alloy 2000 X-flex and the Alda VIII L-flex shafts can be considered the same is revealed. The Alda VIII L-flex as cut for installation into a 43" D1 Driver has 6.6º of torque, while the Alloy 2000 X-flex as cut for installation into a 43" D1 Driver has a torque measurement of 2.82º. In addition, at 43" playing length and D1 swingweight, the Alda VIII L-flex has 216.8 grams of headweight exerting a bending influence upon it during the swing, while the headweight attached to the Alloy 2000 X-flex shaft is 204.4 grams. Interestingly, the Comp50 R-flex shaft has a torque measurement of 2.9º and required a Driver headweight of 212.0g to achieve the D1 swingweight at 43" playing length.

As a result of a full analysis, despite the alleged kick point differences, the Comp50 R-flex and the Alloy 2000 X-flex are the two shafts that are the most similar. While the Alda VIII's much higher 6.6º of torque, working in conjunction with the 216.8 grams of headweight, make the Alda VIII L-flex much softer, and therefore a much different playing shaft than the other two. As the discussion of the shaft testing information moves on to cover torque, the most important points that can be discerned from a deflection and frequency comparison are: 1. From the example of the Comp50 R-flex and the Alloy 2000 X-flex, it is very common for two shafts that are said to be of different flexes by their manufacturer to actually be very similar in their design and playing characteristics; and 2. As evidenced by this single example of the Alda VIII L-flex shaft, torque is extremely influential in determining the overall flex characteristics of a shaft.