Chapter Seven

PUTTING IT ALL TOGETHER - THE DYNACRAFT SHAFT FITTING INDEX

By the late summer of 1990, a little more than a full year after the Dynacraft/Apollo Shaft Testing Project began; we finished compiling the first complete set of test results for the initial group of shafts. There, at our fingertips, were thousands of different sets of numbers. Every conceivable shaft specification for hundreds of shafts had been measured and recorded and lay waiting for conversion into meaningful conclusions that could be used to help golfers select the proper shaft for their game.

While more shafts were on the way to Apollo for additional deflection, kick point and torque measuring, we had quite enough information in our hands from the initial group of sample shafts to get to work. And dive into it we did. However, at this point, you must understand a very important point concerning the original thoughts we had about the Shaft Testing project. Before the tests even started, we became aware that shaft specifications were measured differently by different manufacturers and therefore could not be accurately compared to each other. We naively assumed that all we had to do was measure a large number of shafts on one set of testing equipment and answers would simply fall into place.

Immediately after compiling the test measurements from the initial group of shafts, all of us connected with the analysis side of the test project began to get very excited. In our possession was the most complete stack of truly comparable shaft specification measurements ever independently accumulated at one time in the history of the golf equipment industry! We truly believed the results themselves would provide the answers we were seeking. To satisfy our need for instant gratification, we randomly scanned through a few pages of the test data. Seeing numbers, but little else, it quickly became apparent that very few noteworthy revelations about fitting shafts were going to jump off the pages.

Without a doubt there were fascinating bits of information that made an immediate first impression, many of which have already been presented and examined in the data analysis section (Chapters 3-6) of this book. For example, proof through deflection and frequency testing that a wide range in stiffness does exist within each particular flex level was one of the first, and at the same time one of the most significant, findings that was uncovered by the testing. Knowledge like that was great; something momentous to reveal to the golf industry and, at the same time, something that was really self-explanatory from a fitting standpoint.

After all, if data - hard cold numbers type of data - said that an R-flex version of Aldila's Low Torque graphite design had about the same frequency as True Temper's Dynamic X-flex shaft, wasn't that a pretty easy fitting recommendation to sort out and implement? Dump this version of the Low Torque R-flex shaft from the golf industry's "recommended" list of R-flex shafts for real R-flex players, right?

But on second thought, maybe it wasn't that simple to sort out after all. There have been a lot of R-flex type players who have used this particular version of the Aldila Low Torque R-flex graphite and have NOT complained that it was too stiff. So how could a shaft with an X-flex type frequency or deflection play favorably for a lot of golfers who should have no business, nor any success, using an X-flex shaft?

We know the answer lies in the fact that a higher 5.85° torque measurement of the Aldila Low Torque R-flex - when compared to the 2.48° torque of the Dynamic X-flex - softens the flex of the Low Torque so the average R-flex type player can effectively use the shaft. But how do we know that for sure? How do we know if all R-flex type players can use the Low Torque, or if there are some who cannot? After all, before the Dynacraft/Apollo Shaft Testing Project, we already had an idea that torque affected stiffness. We already suspected that the higher the torque, the softer the overall feel and the lower the torque, the firmer the feel of the shaft would be. What we did not know and what we still had no grasp of after looking at the test data, was exactly how much did torque affect the stiffness? Or, for that matter, how did any of these shaft specifications affect each other? In front of us were thousands of quantified test numbers, yet shaft fitting was still shaping up as a guessing game!

On the heels of the high we experienced from accumulating a ream of uniform shaft specifications measurements came an immediate low. While planning the shaft-testing project, in our naivete we had never taken the time to think how such numbers would be used to accurately fit shafts. Were we going to line up all the deflection measurements and divide groups of shafts by every 1/2” of deflection in an effort to define flex? Were we going to list all of the frequency measurements in order, separate the list in 10 cpm increments and use that to redefine flex? If so, how were we going to account for what effect the torque would have on the flex? If we truly believed torque does affect flex, all the work defining flex by tight little groupings of deflection or frequency would be tossed out the window once torque was included. Mountains of data or not, we knew there had to be interactions between some of the specifications that affect fitting, but immediately after compiling the measurements we had no way of expressing what those relationships would be.

There was no doubt we were being a little harsh on ourselves. After all, if we decided to stop with the data accumulation, we still would have accomplished a remarkable achievement in having measured so many specifications of so many different shafts all under one uniform set of test conditions. We had the industry’s most complete list of independently accumulated, truly comparable shaft specification measurements. That data was uncovering some interesting points about shafts, many of which had never been exposed before.

While some of the new realizations that came from analyzing the shaft specifications were worth a slap on the back and a hearty “well done”, for all of us who had spent countless hours talking about the ramifications of such a project. The ultimate result had to be the fitting information, not just the specification measurements. There in front of us, in the midst of all those numbers, lay a very big problem; how to turn thousands of bits of data into a concise fitting recommendations. After all, the sheer fact that there were so many different shafts to measure in the first place is a pure admission on behalf of the golf industry that golfers need accurate advice about what shaft to use. Thousands of different shafts, made for millions of different golfers. How were the matches to be made?

In Chapter 1, the evolution of traditional fitting principles was traced from a blind trust on behalf of the golfer in the 19th century clubmakers to today’s modern clubmakers. The modern clubmaker uses swing computers and charts to advise golfers independently on the four basic shaft variables of flex, weight, bend point and torque.

Today, there are two ways a clubmaker can fit shafts. First, the clubmakers can study and learn the tenants of traditional clubfitting, gain a knowledge of how to use clubhead speed to conventionally fit flex, and then acquire the skills required to make judgments on the correct weight, torque and bend point for the golfer. Second, the clubmakers can recommend shafts by acquiring a copy of each manufacturer’s own fitting chart, which lists the company’s best shaft for each type of golfer. The trouble with such shaft fitting charts is that they are a creation of marketing and only list those shafts made by one manufacturer. While nearly all shaft manufacturers produce such a chart for their own shafts, the well-informed clubmakers would need to be armed with several charts to do the job. Then when the right “player type” selection has been made for the customer, the clubmaker is still left making a confusing choice between 12-15 shafts.

What is the solution? For the traditional form of shaft fitting, the clubmaker has to learn all the so-called “cause and effect” rules of golf clubs. One would have to study how bend point affects trajectory, learn what clubhead speeds should be matched with what flex, estimate which shaft weight classification matched the golfer’s strength, and so on. Despite the study and training, the traditional shaft fitting knowledge is only helpful if the information describing the shafts is comparable; a point that we know is not the case! So, to fit shafts, the clubmaker is left only with each of the manufacturer’s own fitting charts. To see how confusing, and in particular how impractical, this type of fitting can be, let’s use such a system to fit a typical golfer:

Chart 7-1 - Shaft Selections for A Golfer With 240-Yard Driver Distance from Each Manufacture's Shaft Selection Brochure

Aldila	Apollo	Brunswick	Grafalloy	Ti Shaft
HM-55 S	MasterFlex S	Precision FM 6.5	VHM90 S	Standard S
HM-50 S	MasterFlex SX	FibreMatch 6.5		Pro M66 S
HM-40 S	Torsion Matched S			M54 S
HM-40 L.F. S	AP44 S			
HM-35 X				
HM-30 X				
Low Torque X				

Selecting only five manufacturers, for example there are 17 shaft choices indicated by these manufacturers' fitting charts to be used by golfers who hit their driver 240 yards! Being fair with the manufacturers' shaft selection charts from which these recommendations were obtained, a number of shaft makers try to pair down the selection process by delineating between different types of swing tempo. In other words, whether a golfer swings fast or slow at the ball is a factor of shaft fitting that is outlined in some of the shaft selection charts. If we were to say that our golfer who hit the driver 240 yards and has a fast tempo, the shaft selections offered would be reduced to the following:

Chart 7-2 - Shaft Selections for A Golfer With 240-Yard Driver Distance with a Fast Tempo, from Each Manufacture's Shaft Selection Brochure

Aldila	Apollo	Brunswick	Grafalloy	Ti Shaft
HM-55 S	MasterFlex S	Precision FM 6.5	VHM90 S	Standard S
HM-50 S	MasterFlex SX		FibreMatch 6.5	M54 S
HM-40 LF S	Torsion Matched S			
HM-30 X	AP44 S			

By qualifying our 240-yard driving distance golfer with a fast tempo, we now have reduced the list of possibly shafts from the five different manufacturers' fitting charts from 17 to 13. Delineating further yet to assist in narrowing down the selection, a few of the manufacturers take time to distinguish the golfer by a judgment of playing ability. If we say that our golfer who hits a driver 240 yards with a fast tempo and is an above-average player, the shaft selections offered from the manufacturer fitting charts would be even further streamlined:

Chart 7-3 - Shaft Selections for an Above-Average Golfer With 240-Yard Driver Distance with a Fast Tempo, from Each Manufacture's Shaft Selection Brochure

Aldila	Apollo	Brunswick	Grafalloy	Ti Shaft
HM-50 S	MasterFlex S	Precision FM 6.5	M54 S	Standard S
HM-40 LF S	Torsion Matched S	FibreMatch 6.5		
AP44 S				

By further qualifying the golfer using criteria suggested by the shaft makers, we have trimmed our possible list of shaft options down from 17 to 13, and now down to nine different shafts. At this point the fitting process still comes back down to the clubmaker, with a very large question of just which one of the nine shafts should be chosen. Ideally the golfer would have the opportunity to try out nine drivers built with each of these shafts. But ideally is the operative word in such a procedure because very few shops are so well equipped to allow a golfer the luxury of hitting such a wide variety of different shafts. As a result, using a manufacturer's shaft selection chart to fit a golfer with the correct shaft becomes in essence a popularity contest; if you like the company, you choose its shafts for all golfers you fit.

But let’s take a slightly different approach in an attempt to fit our above-average golfer with a fast tempo that hits a driver 240 yards. Let’s examine the list of recommended shafts from the five different shaft manufacturer fitting charts using the specification measurements obtained in the Dynacraft/Apollo test project. Following is a chart, which lists the nine different shafts for our golfer, with the frequency and torque of each shaft. In all cases the frequency measurements are for the clubs in their cut, assembled form (43”, D-1 swingweight), while the torque measurements are for the cut shafts as they are designed to be used by the golfer.

Chart 7-3 -Frequency and Torque Measurements for Shaft Selections for an Above-Average Golfer With 240-Yard Driver Distance with a Fast Tempo, from Each Manufacture’s Shaft Selection Brochure

Shaft	Flex	Frequency	Torque
Aldila HM-40 Low Flex	S	277 cpm	3.60º
Aldila HM-50	S	277 cpm	2.45º
Apollo AP44	S	260 cpm	2.60º
Apollo MasterFlex	S	264 cpm	2.62º
Apollo Torsion Matched	S	261 cpm	2.59º
Brunswick FibreMatch	6.5	265 cpm	2.98º
Brunswick Precision FM	6.5	264 cpm	2.51º
Grafalloy M54	S	273 cpm	3.35º
Ti Shaft Standard	S	254 cpm	2.45º

Having the proper data to accurately compare the flex and torque for nine different shafts points to a fundamental problem in trying to use the manufacturer’s shaft selection charts to choose the right shaft for our example golfer. The nine shafts indicated by the shaft companies’ fitting charts showed a frequency range of 254 - 277 cycles per minute and a torque range of 2.45º - 3.60º.

While the range can be narrowed by allowing for the fact that the frequency of the Ti Shaft Standard is low only due to the difference in elasticity of the titanium material compared to graphite or steel. Even if the Ti Shaft frequency was tossed out, the range of the nine shafts is still 17 cpm, equivalent to a least 1.5 standard flex levels. Looking at the torque differences, it is somewhat reassuring to see that the range of nine possible shafts has a narrow separation of 1.15º. Still, just looking at the frequency and torque, there are greater variations among the shafts than what should reasonably be expected (especially in flex as indicated by frequency) given the fact these shafts were all recommended to fit the same golfer type.

Defining the Requirements of Shaft Fitting

What we are still left with in trying to use either the traditional form of shaft fitting or in using the manufacturers’ own selection charts is still essentially just an educated guessing game. When we began to look at the thousands of measurements we obtained in the shaft-testing project, in order to see if the data could help formulate a better way to fit shafts, we had to understand just what we were trying to achieve. Ideally, we wanted to take the data and be able to take any golfer and pinpoint one or two shafts that represented the correct fit. To do that required that we first define what we felt to be the most important specifications for shaft fitting.

We discussed what we felt to be the importance of the four-basis shaft fitting parameters - flex, torque, weight and the shaft’s point of maximum bending. We felt strongly that most of out fitting efforts be centered on the flex and torque and finding a definitive way to express the relationship that exists between the two specifications. What we envisioned was a numerical ranking on the overall flex of any shaft that somehow incorporated the measurement of flex and torque we obtained in the testing project. In essence, the goal was developing a stiffness index for shafts.

If the flex and torque could be integrated together into a ranking of overall stiffness, then could the shaft weight and maximum point of bending also be incorporated into fine-tuning the fitting procedure? We searched for possible relationships between the weight, bend point, flex and torque, but nothing definitive came up. We firmly believed that if we could somehow quantitatively pinpoint the way torque was able to change stiffness, the other two specifications of weight and bend point could be added independently to finalize the fitting.

A Theoretical Depiction of the Shaft in the Swing

At the beginning of the swing, during the take-away, the clubhead immediately begins to lag ever so slightly behind the shaft. This is due to the hands and arms having applied a pulling force to the grip end of the club. The weight in the clubhead creates initial resistance, which results into the head lagging behind. At the same time, the shaft begins to rotate ever so slightly in the counter-clockwise direction until the head starts moving. Then the shaft rotates clockwise at some point when the head starts to lead the shaft. The reason the shaft twists is because the center of gravity of the head is offset from the centerline axis of the shaft.

As the club is swung farther back, the clubhead catches up with the shaft at point near the top of the backswing when the hands start to decelerate, because the head in motion wants to remain in motion. At the same time the head rotates open at varying amounts depending upon the distance the center of gravity of the head is away from the centerline axis of the shaft and the amount of torque resistance inherent in the shaft.

A split second after the beginning of the downswing, the shaft is subject to a tremendous amount of force. The force that is applied to the club in the downswing elicits the change in swing direction and causes the head to lag much more dramatically behind the shaft and the hands than it did during the backswing. Enough so, that it is easily visible to the naked eye.

Depending upon the force and acceleration exerted by the golfer as well as the stiffness of the shaft, the shaft may bend significantly or very little as the club starts down. Further in the downswing, with the wrists still cocked the head starts to catch up with the hands due to the acceleration forces. As the wrist starts to uncock, a chain reaction may occur, ultimately that accelerates the head slightly once again. Once the wrists are fully uncocked or released, the hands start to decelerate, but the head now leads the hands just prior to impact, because again the head in motion wants to remain in motion. The head now is bowed forward prior to impact, which increases the dynamic loft of the head. The head also rotates closed at varying amounts depending upon the distance the center of gravity of the head is away from the centerline axis of the shaft and the amount of torque resistance inherent in the shaft.

A third factor occurs during the downswing - the shaft starts to bow downward or flattens the lie angle of the club. As a clubmaker, there are three solutions to remedy the downward bowing of the shaft: choose a club with a more upright lie angle, alter the lie angle more upright or choose a shaft with a higher bend point (stiff tip design). This factor can be added independently to the flex and torque relationship to finalize the fitting.

Once a proper fit has been selected, the golfer should experience both control and feel. This will enable the golfer to repeat his or her swing, with no adjustments necessary. One can theorize if the shaft was totally rigid and totally torque resistant; the golfer would also experience total control. However, such a does not exist, and even if it did, the golfer would be devoid of any feel.

In the case where the shaft is too stiff for the golfer, several symptoms can occur. As the shaft is stiffer than what would be theorized as proper, there would be less bending of the shaft. This would reduce the acceleration of the head as it converts from lagging the hands to leading the hands. This reduces the velocity of the club as it enters the impact zone. The rigid shaft would also not bow forward as much prior to impact, decreasing the dynamic loft of the head culminating into a lower launch angle. Lastly, the golfer can develop a habit of swinging harder than they normally would in order for the shaft to “work”. As a byproduct, the golfer does not have the proper balance at impact.

In the case where the shaft is too flexible for the golfer, the golfer will struggle with their timing or rhythm. Once a golfer swings a club that is too flexible it can cause the shaft to bow far forward at impact and potentially allow the head to rotate closed, creating a less than desired result. The next swing with the same club, the subconscious makes an adjustment by starting to decelerate the hands once the golfer feels the shaft is deflected too much. This results in a less aggressive swing, which usually causes a weak fade or slice. Each time the club is swung by the golfer, there is a constant struggle adjusting the timing and tempo to produce the desired results.

For the shaft to perform to its optimum level for a golfer, the amount of force generated by the golfer needs to match the stiffness and torsional properties of the shaft. The amount of force generated by the golfer can be gauged somewhat by the swing speed at which they swing the club. An accurate fitting must be able to integrate the bending (flex) and twisting (torque) properties of the shaft together in an overall expression of feel and performance.

Expressing the Relationship between Flex and Torque

In an attempt to begin defining the relationship between flex and torque, we felt that the because a shaft bends far more than it twists, any expression of the interaction of the two parameters had to weigh more heavily on the flex. Because we obtained quantitative measurements to express the flex and the torque of the shaft, we began to look for a mathematical way to express the two specifications together. In the landmark study, “The Search for the Perfect Swing”, authors Alistair Cochran and John Stobbs theorized that it could be possible to create a mathematical model, which could depict the action of the shaft in the swing. In the book they state: “In science a model is a representation of something complicated or ill-understood by something simple or familiar. A scientist can actually build such a model with wood, metal, plastic, etc., and carry out tests in detail how it works; or else, and more commonly in point of fact, he can describe his model mathematically, and work out on paper all he wants to find out about its behavior (sic). A model must, in the first place, faithfully represent the observable outward effects of whatever it is he is using to study. How much it predicts is the acid test of how much a model is worth in practice.”

This became the goal of the fitting side of our shaft-fitting project; to develop a model, which could accurately predict the overall stiffness of shafts. Rather than embark on a search to perfectly express the true physical relationship of shaft stiffness and torque - a task for which none of us on the research team were professionally qualified. What we began to seek was a mathematical way to set up a stiffness index, or in better terms, an orderly numerical ranking of stiffness with the effect of torque included for all shafts that were tested in the project. To act as a guide for our search we had two comparative studies to which compare and check our findings. First, we had copies of each manufacturer’s shaft selection chart, in which the shaft makers predicted the stiffness of their shafts in accordance with what swing speed would be required for each shaft. Second, we had the results, as imprecise as they have may seemed, of a continuous golfer field study group, which provided us with much needed feedback on the overall stiffness of various shafts.

While working with live golfers in exploratory fitting sessions did leave open great chances for error in the accuracy of the feedback, it also served as a valuable opportunity for information as well. Because we at Dynacraft could draw upon the hundreds of shafts from our inventory to fit the wide array of our test golfers, we frequently were able to successfully select a complimentary shaft for these golfers. In other words, in a normal retail fitting and selling environment - such as a typical clubmaking shop or pro shop - all too often the most desirable fit in not achieved. Sometimes a lack of adequate shaft samples may prevent the perfect fit, in other instances a lack of time prohibits the correct match from coming about. But in our situation, where golfers are fit on a daily basis and research on golf equipment is a constantly on-going project, we had plenty of time and shaft samples to choose from. Once the proper fit was verified, not only by the player feedback, but through actually results from a pair of Sportek swing analyzers, we felt our human testing reports were very reliable in helping creating a stiffness index which incorporated the flex and torque together.

Equally important to the field studies as a way to verify our proposed numerical ranking index of overall flex/torque stiffness were the shaft manufacturer’s selection charts. Operating from the assumption that a manufacturer has absolutely nothing to benefit from wrongly advising golfers into the proper shaft, we spent a great deal of time studying each manufacturer’s recommended fitting charts. We strongly believed that not only did each manufacturer devote a great deal of energy (and resources) to figuring out which type of player their shafts were best suited. We also assumed that the manufacturers had created their fitting recommendations with some type of a flex-to-torque relationship in mind too. After all, in our conversations with shaft manufacturing and design personnel, everyone agreed that torque did have an effect on stiffness and thus had to be taken in account when suggesting a proper shaft selection.

The reason we knew that the shaft manufacturers had to be identifying a relationship between flex and torque was evident from reading their selection charts. For example, we will use of one of the fitting guides offered by Aldila Shaft Corp. for its 1992 shaft product line.

Under the 85-100 mph clubhead speed column, the flexes of the recommended shafts for a golfer are listed in order as HM-55 Regular, HM-50 Regular, HM-40 Regular, HM-40 Low Flex Regular. After the HM-40 Low Flex the listing change the flexes and then continue with the HM-35 Firm, HM-30 Firm and the Low Torque Firm. Aldila uses slightly different terminology to describe its flexes. When compared to traditional flex descriptions, Light is the same as L-flex (L), Regular corresponds to Regular (R), Firm matches Stiff (S), and Strong coincides with Extra Stiff (X). Under the 100-115 mph column, the condition exists in which the company switches from one flex to another. The significance of this observation is as if to say that all golfers with the same swing speed do not necessarily need the same flex. Hence Aldila, in essence, is saying that the lower torque (HM-55, HM-50, HM-40 all have lower torque ratings than the HM-35, HM-30 and Low Torque), the softer the flex that should be to any level of golfer.

Further study of other shaft manufacturer's selection charts also revealed the same expression of the relationship of flex to torque, or in some cases of flex to bend point / kick point. For example, within Grafalloy's Select-A-Shaft™ fitting guide, under the different clubhead speed levels, different flexes of the various recommended shaft designs are advised. Again, the lower torque rated shafts are recommended with the softer flex within each category. This method of prescribing different flexes for golfers with the same swing speed might be thought to be limited to graphite shafts, in which torque can independently be changed from the flex by the design engineers.

A short look at Apollo's fitting pamphlet showed that the same practice of advising a different flex for a different shaft pattern for golfers with the same swing speed also is done with steel shafts. Under the heading of "Competent Single Figure Handicap" with the column titled "Fast 90-100 mph", can be found three different shaft flexes recommended over five steel shaft patterns. Apollo recommends the MasterFlex 3 (an R/S level flex), MatchFlex 4 (an S-flex), Torsion Matched Mark II R-flex, the Spectre S-flex and the AP44 R-flex. Because all these shafts are steel and therefore very close torque measurements to each other, the only possible reason for Apollo's recommendation of different flexes for different patterns is because of bend point / kick point. Apollo's rationale in this case must be that the lower the kick point, the firmer the flex that is recommended. Hence the S-flexes of the mid kick point Spectre and MatchFlex are suggested, while the R-flex versions of the higher kick point AP44, Torsion Matched Mark II and MasterFlex are chosen.

Every single manufacturer's shaft selection chart we studied used either golfer clubhead speed or average driver distance, or both, as the primary means of indicating which golfer was best suited for which particular shaft and flex. However, we hoped our search for a stiffness index ranking for all the shafts tested would allow us to pinpoint clubhead speeds that were a little closer in range than the levels offered in most of the manufacturers' selection charts. In the fitting guides from Aldila and Grafalloy, clubhead speed fitting column were separated by 15 mph increments while from both Apollo and Ti Shaft, the separations were 10 mph.

From working with many golfers and having the luxury of being able to obtain accurate clubhead speed measurements in the field studies, we felt strongly that 10-15 mph was just too wide of a swing speed range to expect a shaft to fit all golfers within that level. For example, in Aldila's fitting chart, there were seven different shafts that are listed as possibilities for a golfer who swings a driver between 85-100 mph. To emphasize why such a wide range is difficult to work with in fitting, Chart 7-5 includes a listing of the frequency and torque measurements of these seven Aldila shafts.

Chart 7-5 - Frequency and Torque Measurements of Aldila Shafts Recommended for Golfers with 85-100 mph Clubhead Speed

Shaft	Flex	Frequency	Torque
Low Torque	Firm	272 cpm	5.83°
HM-30	Firm	271 cpm	4.10°
HM-35	Firm	273 cpm	3.60°
HM-40 Low Flex	Regular	267 cpm	3.65°
HM-40	Regular	262 cpm	2.89°
HM-50	Regular	263 cpm	2.45°
HM-55	Regular	263 cpm	1.81°

Note: All shaft data represents measurements obtained from driver shafts that were tested in the cut form at a length of 43" and D-1 swingweight.

The chart of recommended shafts for a golfer with an 85-100 mph driver swing speed shows how Aldila does make some allowances for the interaction of the flex and torque. To explain, of the four regular flex shafts, The HM-55, HM-50 and HM-40 all have virtually the same frequency, while their torque measurements increase gradually from 1.81-2.89°. The last regular flex shaft, the HM-40 Low Flex, has a slightly higher 267 cpm frequency and a slightly higher 3.65º torque measurement than the other three regular flex shafts.

When the list of seven recommended shafts moves into the firm flex, note the frequency and the torque of the three firm flex shafts increase over that of the regular flex shafts. Although the frequency and torque of the three firm flex shafts is greater than the four regular flex shafts, the measurements are very similar among the firm flex shafts. Knowing that a higher frequency combined with a lower torque are both factors which increase stiffness, it is possible to see the relationship of the flex and torque of the shafts and why the seven shafts are all recommended for the 85-100 mph player.

From a clubhead speed standpoint for fitting, because of the very low torque, the HM-55 has to stand at the high end of the swing speed range. The HM-50, HM-40, HM-40 Low Flex, which all measure somewhat similar in an overall combined relationship of flex and torque, are seen as suitable for the middle of the 85-100 mph swing speed range. While the HM-35, HM-30 and Low Torque, due to their much higher torque measurements, have to be standing at the lower end of that range. Here is a key point that represents how we were trying to structure our approach to setting up a stiffness index for shafts. Aldila says in its selection guide that all seven of their shafts can fit a golfer with a swing speed in the 85-100 mph range. But what the guide doesn't specify is whether the HM-55 regular was designed for the upper end and the Low Torque for the lower end of the range. In formulating a fitting index, we wanted to use the data to come up with a way to make sure that the 85 mph golfer doesn't try to use that HM-55 shaft.

The only problem with the Aldila fitting chart (and others like it) is that is does not actually come out and make such a statement. Instead their fitting guide simply offers all seven shafts for any golfer with a swing speed of 85-100 mph. However, a closer estimation of clubhead speed for all shafts would be helpful. Such as the HM-55 R is for 100 mph, the HM-50 R, HM-40 R and HM40 Low Flex R are for 92.5 mph, and the HM-35 firm, HM-30 firm and Low Torque firm are for the 85 mph swing speed. This is the type of information that would qualify as a stiffness ranking and be, in fact, be the type of fitting index we were looking for.

The Evolution of a Stiffness Index

In tackling the problem of creating a true shaft-fitting index, the first hurdle was purely mathematical. How did we expect the numerical ranking of the stiffness of shafts to evolve? In a list of Shaft #1 through #400, with the higher the number the stiffer the shaft? Somehow, we felt that the formula that incorporated the combined stiffness and torque - in their proper proportion to each other and expressing how one change the other - had to be found. To begin a search for our stiffness index, in all honestly started with a simple formula; dividing the frequency of each club by the measured torque of the shaft. This, of course, was of no help because the numbers generated showed no resemblance to the manufacturers' fitting guides or the numerous entries from our field studies. With the first rudimentary attempt, many shafts that were softer ended up with a higher numerical designation than shafts we knew felt much stiffer based on our field study notes.

Still we had to remember that our goal was to establish and orderly index of stiffness which could pick up on the fact that torque did change the stiffness of a shaft. Two points led our search for the next step. First, from our study of the bending and twisting that occurs during the swing, the shaft bends far more than it twists. Therefore, we had to turn our search for a stiffness index that would utilize the frequency measurements as a primary factor and the torque as a sub-factor. Second, from the golfer field tests we had received considerable feedback that many shafts with a high frequency/high torque shafts felt similar to shafts that were designed with a low frequency/low torque combination. If in a fact such shafts with very different specifications were equivalent, our shaft stiffness index had to make those allowances.

Another point of data that surfaced and led us to believe that we had to decrease the contribution of torque in the development of the index came from observing the relationship of frequency and torque among steel shafts. While the Dynacraft/Apollo shaft-testing project did measure the specifications of hundreds of steel shafts, we focused much of energy on the relationship of flex and torque on graphite shafts. Quite unlike the data we had obtained from testing the graphite shafts, among all the steel shaft frequencies displayed a wide range while the torque did not. Because golfers do report that there are very distinct stiffness differences between the steel shafts, even though the torque is almost constant, this led us to believe that our judgment in using only a portion of the shaft torque in the mathematical search for a stiffness index.

An important point to note here: at this point in our search to create a shaft fitting /stiffness index, we decide to concentrate on the cut driver shaft data. This decision was based on the fact that the driver shaft data was more readily available from the manufacturers themselves. Once we found a logical combination of the flex and torque that worked reasonably well for the drivers, we would then concentrate again on the irons.

We next divided the frequency by the square root and then the cube root of the torque in attempt to apply our theory. After analyzing the reams of papers that constituted our efforts to create a stiffness index, it finally begun to show a sequence that grouped shafts together that followed the manufacturers' shaft selection charts. In an effort to afford better understanding, recognize that we were not trying to come up with an absolute parameter. What we were doing at this point was trying to come up with a numerical ranking for the overall stiffness of shafts that would coincide with a provisional clubhead speed rankings we had accumulated from both the manufacturers' fitting charts and the feedback we received from live golfers.

At this point an interesting situation - which reinforced our belief that we were on the right path - began to emerge. In many of the shafts, the numerical indexing was approximately twice the driver swing speed that was stated for each shaft in the manufacturers' selection guides. In other words, a driver swing speed designed for a player with a swing speed in the low 90's was emerging from our calculations with numerical values of approximately 180. Looking for a much greater correlation, we began to reference the information we obtained from the golfer field studies to look for the clubhead speeds of our test golfers and note what shafts fit them. Just as in the case of comparing our index numbers to the manufacturers' fitting charts, the frequency divided by the cube root of torque yielded an index number that was approximately twice the swing speed of the test golfer.

Now we were prepared to begin testing our preliminary index with live golfers. In an attempt to relate the index to actual clubhead speed, we calculated a provisional Dynacraft Shaft Fitting Index (DSFI) for each shaft by taking the frequency and dividing by the cube root of torque, and dividing that quotient by one-half. Through the fall of 1990 into the spring of 1991, the Dynacraft technical staff received and accumulated reports from clubmakers who had been surreptitiously given our fitting guide. The feedback from both the local golfers and the recommendations made to customers over our technical line were positive.

At first we were not all that surprised that what we perceived to be a reasonably accurate shaft fitting index work so well. After all, the main point incorporated by the original DSFI was not so much the relationship of flex to torque, but rather a more accurate identification of the flex performance of each shaft on its own. Remember, until the Dynacraft/Apollo shaft-testing project results were studied, no one had known the certainty that the same shaft levels were different from shaft to shaft and manufacturer to manufacturer. With the benefit of having deflection and frequency measurements for hundreds of different shafts, at the very least we had gained the ability to steer a golfer away from shafts that happened to test out much stiffer than what their flex designation had previously indicated. As a result, from the standpoint of flex, we were confident that we were using these test results to at least fit shaft stiffness accurately. What we still were not completely sure of was whether we were able to accurately identify the affect of torque on the overall stiffness of the shafts.

Because of the fact composite shafts vary so much more than steel in the parameters of frequency and torque, we felt one of the best ways to measure the success of integrating torque into the index was metering the results of the graphite shaft recommendations we were making. At first, a comparison of the DSFI swing speed to know options for feel of various shafts told us that we ought to be on the right track. By comparing the original DSFI calculations for swing speed for all types of graphite, we found that graphite shafts with high frequency and low torque had much higher index numbers than shafts with high frequency and high torque measurements. In other words, shafts with high frequency and low torque required higher swing speeds than high frequency shafts with high torque.

Therefore, our preliminary DSFI calculation of 103.86 mph for a shaft such as the Aldila HM-40 (271 cpm / 2.22º torque for the Firm flex) was much higher than the 77.13 DSFI predicted for the Apollo G100 (265 cpm / 5.07º torque in the S-flex). In turn, the feedback we had received from golfers who hit shots with each shaft agreed; the HM-40 felt considerably stiffer than the G100, even though they were both S-flex shafts!

We continued to gain further confidence that we were moving in the right direction from noting the DSFI calculations for a number of very popular shafts for golfers of average ability with the feedback we received about these shafts. For several years, True Temper's TT Lite has been the largest selling steel shaft and Aldila's Low Torque the most popular graphite shaft in clubmaking.

Although there was only titanium manufacturer, we decided to include this shaft because of its unique combination of low frequency and low torque. The original DSFI calculations for the L, R and S-flex versions of the TT Lite, Low Torque and Ti Shaft Standard driver shafts were as follows:

Chart 7-6 - Comparison of Original DSFI for Aldila Low Torque, True Temper TT Lite and Ti Shaft Standard DriversChart

Shaft	Flex	Frequency	Torque	DSFI Rating
Low Torque	L	246 cpm	4.68º	73.53 mph
	R	277 cpm	4.72º	82.57 mph
	S	290 cpm	4.10º	90.60 mph
TT Lite	L	237 cpm	3.25º	80.00 mph
	R	255 cpm	2.87º	89.72 mph
	S	266 cpm	2.64º	96.23 mph
Ti Standard	L	237 cpm	3.29º	79.67 mph
	R	243 cpm	2.60º	88.36 mph
	S	254 cpm	2.45º	94.21 mph

Note: Low Torque measurements in this chart were performed on the combination flex version. There were several versions of the Aldila Low Torque; thus their DSFI ratings will differ as well.

The original DSFI calculations for all three shaft designs showed some similarities in their overall stiffness, even though the combination of frequency and torque varied considerably. Most of the fitting charts, plus the data from our field testing, showed that the average lady golfer rarely swung a driver over 70 mph. Thus, the L-flex versions of each of these shafts may be too firm for whom they were designed. The average male golfer swings the driver in the mid-80 mph and maybe why each of these R-flex shafts is the most popular in each material classification. Lastly, the typical S-flex player swings the driver in the mid-90's and over.

Our goals in creating a shaft fitting index, even though is was not intended to be a true mathematical model of what happens in the golf swing, but more so in producing a best fit formula to express why certain golfer use certain shafts well. We had obtained comparable data on hundreds of shafts of the same length and swingweight and came up with an analytic approach in producing an index which we hoped could help clubmakers fit shafts more accurately.

Flaws in the System Give Way to a Better DSFI

We had experienced what we felt was a significant level of success in anonymously using the original DSFI for driver shafts on our field study groups and on our technical line. After which, we decide to "go public" with the index in order to obtain much more widespread feedback about our new fitting system. In the June 1991 issue of Clubmaker's Digest magazine, the monthly publication composed and distributed by Dynacraft, we published a series of articles which more formally introduced nearly 30,000 clubmakers to the original Dynacraft Shaft Fitting Index.

Almost immediately after the issue was mailed, clubmakers began to report a much higher degree of success in making the correct shaft selection for their customers, at least the majority of the cases. Occasionally we still heard from a clubmaker who had used the index without satisfactory results, though this certainly was the exception and not the rule. In those cases we tried to keep note of the fitting recommendation that had been made in an effort to possibly identify a trend that could pinpoint and flaws existing in the DSFI system. Before long is was easy to see the primary problem that clubmakers were having with the concept - the original DSFI was working very successfully for fitting shafts in woods; it did not, however, work nearly as well for fitting iron shafts.

As previously mentioned the original DSFI calculations were experimentally conceived to create a stiffness index by combining flex and torque for all shafts. However, the DSFI was created using only the data that came from the testing of driver shafts.

Therefore, when the original DSFI formula was used to create a stiffness index for the #5-iron shafts, there was virtually no correlation (and no practical application for fitting). Since the #5-iron shafts all had a much higher frequency and a much lower torque, all the DSFI ratings were simply too high. The DSFI rankings of the #5-irons were in a logical order of overall stiffness, but wasn't in relationship to the DSFI rankings and the swing speed ranges for a #5-iron.

Here was one of the tricky points, which, as a result of our work on the data connected with the wood shafts, had become a major part of the DSFI. In the original wood shaft calculations, we set up an index formula so that it would correspond to known clubhead speed levels. We felt the DSFI had to list a clubhead speed for each shaft, not just so golfers and clubmakers could better relate to the fact that this was the index, but so they could easily use the data we had obtained to fit the golfer into the right shaft. Had we pursued setting up the index in just a ranking order of overall stiffness (#1 through #400), it would have been difficult to relate to clubmakers just how to use the index. Should a strong golfer use shafts #1 through #75, while ladies used shafts # 325 through #400? Such an index would have gotten the point across, but would have done little for helping select the right shaft.

At the time of this study, no manufacturer has ever published recommended #5-iron swing speeds for any of their iron shafts. Did a golfer who swings the driver 100 mph then swing the #5-iron 90 mph? 80 mph? Soon we realized that such information was unknown ever since the late 1970's when clubhead speed became accepted as a way to fit shafts, no one had ever bothered to question whether a clubhead speed chart was needed to fit irons. We, like everyone in clubfitting, had assumed that when you found the proper fit in a wood shaft, you automatically used the matching iron version and flex of that shaft.

There were two questions that we wanted to investigate to see if a golfer necessarily needed the same shaft pattern and flex in both the wood and iron model. First, did the wood shaft match the iron shaft knowing they were different lengths and tip diameters? Secondly, did a golfer swing the driver the same as the #5-iron to warrant using the same shaft pattern and flex? These answers would help understand why some of the recommended shaft selections did not accurately fit the golfer.

Do all the shafts in a set, from the woods through the irons, increase in stiffness at the same proportionate rate regardless of shaft pattern? The rate that stiffness increases as a shaft become shorter is dictated largely by the trimming of the shaft. The tip end of nearly every shaft is the weakest portion of the shaft due to the smaller diameter than the butt end of the shaft. During the assembly process, if more is trimmed from the tip end than the butt (which is the case with most parallel tip steel shafts) the frequency will increase at a greater rate than if a shaft is trimmed all from the butt (which is the case in many parallel tip graphite shafts). This means the frequency slope, or rate of stiffness increase through the set, will be different for the various types of shaft designs.

To illustrate this point, Charts 7-7 and 7-8 show the relationship between average driver and #5-iron frequency and torque in both steel and graphite. In each case, the men's flex drivers and #5-irons are assembled at D-1 and 43" and 37.5" respectively. The ladies flex driver and #5-iron are C-6 and 42" and 36.5" respectively.

Chart 7-7 - 2000 Frequency and Torque Relationships for Woods Verses Irons - Steel Shafts, Industry Averages

Flex	Frequency		Wood vs. Iron	Torque		Wood vs. Iron
	1W	5I	Relationship	1W	5I	Relationship
L	234	285	82%	3.32	2.12	64%
A	234	279	84%	3.30	2.12	64%
R	252	301	84%	2.96	1.93	65%
S	264	316	84%	2.73	1.75	64%
X	272	324	84%	2.61	1.69	65%

Chart 7-8 - 2000 Frequency and Torque Relationships for Woods Verses Irons - Graphite Shafts, Industry Averages

Flex	Frequency		Wood vs. Iron	Torque		Wood vs. Iron
	1W	5I	Relationship	1W	5I	Relationship
L	237	276	86%	5.76	4.22	73%
A	240	278	86%	5.27	4.12	78%
R	254	293	87%	4.68	3.67	78%
S	267	307	87%	4.43	3.57	81%
X	278	315	88%	3.36	2.93	87%

Reviewing Chart 7-7, the average progression of stiffness and torque between steel drivers and #5-irons amongst the various flexes are linear. In Chart 7-8, the progression of stiffness, and more noticeably torque, graphite shafts did not possess the same linearity between flexes. In comparing the steel and graphite shafts, the graphite driver shafts were slightly stiffer than their steel counterparts, but the graphite #5-irons shafts were more flexible than the steel #5-iron shafts. In the field studies, there were a higher percentage of cases where the graphite iron shaft did not fit the golfer the same as the corresponding wood shaft.

Even among steel shaft patterns, there were certain exceptions to the proportionality of flex and torque. For example, TT Lite woods were consistent with the average frequency and torque. However the TT Lite iron shafts measured a higher frequency and lower torque verses the iron averages. In other cases, such as the Microtaper, the #5-iron shafts showed a lower-than-average frequency and higher-than-average torque readings compared with other steel shafts in the same flex. As discussed in Chapter 4, graphite shafts are more flexible in relationship to the woods when compared to steel shafts. Just because the matching wood and iron shaft have the same name, does not necessarily indicate that the shafts match because the each shaft has different tip diameters and trimming instructions.

The other assumption that is made is if a shaft works well in the woods, then the golfer should use the same shafts in the irons because a golfer has the same swing throughout the set. Chart 7-9 shows five different golfers Driver swing speeds verses the #5-iron swing speed.

Chart 7-9 - Field Study of Golfer Swing Speeds (Driver vs. #5-iron)

	Golfer 1		Golfer 2		Golfer 3		Golfer 4		Golfer 5	
	1W	5I	1W	5I	1W	5I	1W	5I	1W	5I
	105	79	90	71	88	77	85	66	108	90
	103	81	91	72	89	77	83	67	107	91
	105	81	90	70	89	77	82	69	109	90
	106	81	92	72	88	76	85	78	107	91
	105	79	91	75	91	77	86	69	108	90
Averages	104.8	80.2	90.8	72.0	89.0	76.8	84.2	67.8	107.8	90.4
5I vs. 1W Percentage	76.5%		79.3%		86.3%		80.5%		83.9%	

From Chart 7-9, Golfer #1 and Golfer #5 possessed similar driver swing speeds, however, the #5-iron velocities were quite different. Again, Golfer #2 and Golfer #3 had similar swing speeds with the Driver as well, but not the #5-iron. Does this mean that golfer’s may not need similar flexes throughout their set? This might explain one reason the shaft recommendations provide good results with the Drivers, but not always on the irons.

Since this study was completed years ago, we have had an opportunity to measure over 1000 golfers and have seen some surprising results. There has been occasions where the difference in Driver and #5-iron swing speeds have been as much as 30 mph, to certain golfers having the same reading. As golfers, we attempt to swing the same way throughout the set, but that is not always the case. There could be three situations, which might explain this phenomenon.

The first, and most obvious, a golfer does swing the same way from club to club. Whether it is aggressive or fluid from swing-to-swing, it is nevertheless consistent. A byproduct of this is there is a certain percentage the Driver and #5-iron swing speed which could be constituted as average.

The second situation is when a golfer has a tendency to be a hitter with the woods, especially the Driver, but more of a swinger with the irons. This is a natural tendency for many golfers because the golfer is trying to obtain maximum distance off of the tee, but swings within themselves with the irons for distance control. This tendency will usually cause a larger percentage gap between the Driver and #5iron swing speed readings as in the case of Golfer #1.

The third situation is when the golfer has difficulty with the woods and not the irons. Whether the clubs are too long, too heavy, or simply lacks confidence in hitting the ball in the proper direction, the golfer is less likely to swing to his or her natural ability. However, the irons may not pose any problems and allow the golfer to swing in an athletic manner. The tendency in this case is the percentage between the Driver and #5-iron is very high as in the case of Golfer #3.

We had found two reasons why the Driver shaft recommendations would work well, but not necessarily with matching #5-iron and Driver choices. Due to completely different tip diameters and tip trimming methods, a wood and iron shaft of the same pattern may not closely match as a set as was once thought. The other factor is that golfers do not always swing the same way with their Driver as they do with the irons.

Whiles these discoveries were very important in our study, for the time being we had to set that matter aside and devote all of our energies to rethinking the original DSFI formula. In addition to the lack of iron correlation, the publishing of the original DSFI formula in the June 1991 issue of Clubmakers Digest also provided us with additional feedback that a few of the Driver swing speeds were a bit too high or low. This, plus the discoveries we had made about the iron DSFI ratings, led us to believe we needed to set up the index so the torque dimension was not “penalized” as much in the new calculation. In the end after much research, the torque contribution in the calculation was changed from the cube root to the fifth root and three numerical constants were added to the original DSFI formula.

In the original DSFI calculation, frequency was divided by the cube root of torque, and then divided by two. All of this was in an effort to create an index that closely resembled the suggested swing speeds of the shafts in the various manufacturers’ selection guides and to match the data we had obtained in our field study fitting of golfers. In the revised index calculation, we eventually divided the frequency by the fifth root of its torque and then multiplied by a new adjusted constant of 0.45. This constant was a product of many attempts to arrive at a full set of DSFI ratings that would be more in line with the data we had obtained from the manufacturers’ shaft selection charts and from the field study for both wood and iron shafts.

In order to relate the DSFI to iron shafts, we implemented two other constants we felt necessary, a weight constant and a length constant. The weight constant we derived was based on the study of all of the shafts in our testing project, with the 43” Driver length constant set at 1. From our comparison of the static weight of the cut Driver, was on average 87% of the cut #5-iron, both at D-1 swingweight. Because of the principle, which says the heavier the total weight of the golf club, the slower it will be swung, we viewed this weight relationship for the DSFI to be inversely proportional. Hence, for the DSFI calculations that involved Driver shafts we used the constant of 1 and for calculations that involved the #5-iron shafts we used a constant value of 0.87.

In addition to a weight constant, to further integrate the #5-iron data into the DSFI we felt the need to set up a length constant as well. Besides the weight increase, the #5-iron swing arc was greatly reduced from a Driver. This, the #5-iron had to be swung slower than the Driver. Interestingly, the relationship between the length of the #5-iron is also 87% of the length of the Driver. For DSFI calculations that involved 43” Drivers, the length constant was 1, while the length constant for the 37.5” #5iron would be a derivative of 0.87.

Despite the similarity in the difference of the weight of the shaft and the length of the #5-iron compared to the Driver, we felt that the weight and the length constants needed to be treated separately in the DSFI calculation. The swing speed if more of a factor of length, more so than it is the weight of the club. Visualize a golfer swinging a 43” Driver and then swings a 37.5” #5-iron. If both swing in a circle, obviously the arc created by the Driver is much larger than the #5-iron. Even though the radius, or length of the #5-iron is 87% of the Driver, the circumference of the #5-iron swing is not 87% of the Driver. The area of the swing arc is much smaller with the shorter club, thus the length constant for the 37.5" #5-iron was required to be $(87\%)^2$. This is due to the fact that calculating the area of the circle requires squaring the radius.

For lengths longer or shorter than the men's standard Driver and #5-irons, the length and weight constants will change proportionately. This will be evident when we discuss ladies length clubs and ultra-lightweight graphite shaft assembled overlength. The procedural outline in the Shaft Fitting Addendum will provide conversion factors for the various assembly lengths.

After fine tuning, the final DSFI formula that we used to set up the complete Driver and #5-iron indexes was:

$$F / T\hat{}^{1/5} \times (0.45) \times (W) \times (L)^2$$

Before we go on, we cannot stress enough how important it is to understand that the function of the DSFI was to establish an index, which would that would tie in the swing speed of the golfer based on the actual measured flex and torque of the shaft. The index correlated to both manufacturer's fitting charts and what matched to golfers in the field studies based on feel and performance. As a result the DSFI calculations were conceived to represent the minimum swing speed for each shaft. This formula was not intended as, nor should it be considered a quantitative method for physically describing the true interrelationship of stiffness and torque. Such a study would require far more sophisticated engineering understanding of every aspect of bending of the shaft during the swing - at high speeds, medium speeds, and low speeds - a task that would truly be staggering in creating an index of overall stiffness. Therefore, DSFI stands for just that - an index, which accurately ranks the performance effect that torque has on the stiffness of the shaft.

Comparing DSFI Rating to Manufacturer's Fitting Charts

Earlier in the chapter, we compared shafts in the manufacturer's fitting charts to the actual measured specifications we obtained in the testing project. Charts 7-8 and 7-9 demonstrates how the DSFI formula, based on the measured frequency and torque of the test shafts, compare to the recommendations made by the manufacturers.

Chart 7-8 -Frequency and Torque Measurements for Shaft Selections for an Above-Average Golfer With 240-Yard Driver Distance with a Fast Tempo, from Each Manufacture's Shaft Selection Brochure

Shaft	Flex	Frequency	Torque	DSFI
Aldila HM-40 Low Flex	S	277 cpm	3.60°	96.48
Aldila HM-50	S	277 cpm	2.45°	104.19
Apollo AP44	S	260 cpm	2.60°	96.66
Apollo MasterFlex	S	264 cpm	2.62°	97.98
Apollo Torsion Matched	S	261 cpm	2.59°	97.09
Brunswick FibreMatch	6.5	265 cpm	2.98°	95.86
Brunswick Precision FM	6.5	264 cpm	2.51°	98.83
Grafalloy M54	S	273 cpm	3.35°	96.46
Ti Shaft Standard	S	254 cpm	2.45°	95.55

Chart 7-9 - Frequency and Torque Measurements of Aldila Shafts Recommended for Golfers with 85-100 mph Clubhead Speed

Shaft	Flex	Frequency	Torque	DSFI
Low Torque	Firm	272 cpm	5.83º	86.03
HM-30	Firm	271 cpm	4.10º	91.97
HM-35	Firm	273 cpm	3.60º	95.09
HM-40 Low Flex	Regular	267 cpm	3.65º	92.74
HM-40	Regular	262 cpm	2.89º	95.35
HM-50	Regular	263 cpm	2.45º	98.93
HM-55	Regular	263 cpm	1.81º	105.11

Note: All shaft data represents measurements obtained from driver shafts that were tested in the cut form at a length of 43" and D-1 swingweight.

With the exception of the HM-55 R-flex shaft, all the DSFI ratings fell within the manufacturer's recommended swing speed ranges. The whole intent of the DSFI was to enable clubmakers to make better- educated shaft recommendations for their customers. We had felt the 10-15 mph range was maybe too wide of a swing speed range to expect to fit all golfers within the range. For example, in Chart 7-8, the HM-50 fell on the high side of the range while the Ti Standard fell on the low end of the range.

It should be noted that not all DSFI ratings fell within the ranges the manufacturers provided. This is especially true of L-flex shafts. As we have noted in previous chapters, the L-flex frequency, deflection and torque were very close to A-flex shafts. Yet, many manufacturers' fitting charts place the L-flex range 10-15 mph lower than the A-flex range. To put this in perspective, examine Chart 7-10, which shows the average DSFI rating compared to traditional fitting recommendations.

Chart 7-10 - Average DSFI Ratings for Each Flex vs. Traditional Fitting Recommendations

Flex	Steel	Graphite	Traditional
L	80.01	72.58	Up to 60 mph
A	82.93	77.59	60 -75 mph
R	91.28	84.01	75 - 90 mph
S	97.18	89.09	90 - 110 mph
X	101.03	96.40	110 mph and up

All L-flex shafts measured at 42" and C-6 swingweight. Men's flex shafts measured at 43" and D-1 swingweight.

Traditional fitting represents ranges between flexes of 15-20 mph gaps. Since the shaft-testing project covers the majority of popular steel and graphite shafts, the average separation should have shown consistency between flexes if one was to follow the traditional fitting methods. However, this is simply not the case. The separation of frequency and deflection in our testing showed that adjacent flexes were not consistent.

Examining Chart 7-10, there is little difference between L and A-flex DSFI ratings in steel shafts. Many of the steel shafts that are L-flex is derived from an A&L combination flex shaft. The difference between what constitutes an L-flex and an A-flex is only 1" of tip trimming. Many of the R and S-flex shafts are derived from R&S combination flex shafts. The difference in tip trimming is 2", which separates the two flexes apart. Therefore, it is logical that the separation between the R to the S-flex shafts be twice that of the L to the A-flex shafts. The DSFI demonstrates this relationship. The DSFI range between the L-flex to the A-flex is a little less than 3, while the difference between R-flex to S-flex are approximately 6.

The deviation in traditional swing speed ranges may be much too great. The difference between the low end of A-flex is 60 mph, while the low end of X-flex is 110 mph. Yet the difference in the average frequency is only 36 cpm in steel shafted Drivers.

Each mph would equate to less than 3/4 cpm in frequency. Therefore, if the industry average of 10 cpm per flex was correct, then the separation in each flex range should only be 7 mph, which is half of the difference in the traditional fitting method, but very close to the average DSFI ratings.

On average, the DSFI of steel shafts are 6.5 mph higher than graphite shafts with the same flex designation. Even though the average frequency of graphite is slightly higher than that of steel, the torque readings are considerably higher than steel. Using the DSFI formula, the higher torque offsets the higher frequency, thus the discrepancy between steel and graphite shafts. However, there may more than this that meets the eye.

Factoring in Shaft Length and Weight

There are two main reasons why the manufacturers produce graphite shafts to be more flexible than steel. In the search for a true "apples-to-apples" comparison among shafts, we assembled the graphite-shafted Drivers the same length as the steel-shafted Drivers. Today, graphite-shafted Drivers are manufactured longer than steel-shafted clubs. As discussed earlier, when we were developing the DSFI formula, length plays an important factor. The #5-iron was shorter than the Driver, yet designed to be stiffer for a good reason. The longer swing arc generated by the golfer with a Driver has more time for a flexible shaft to recover at impact. As the swing arc becomes shorter, there is less time for the shaft to straighten out prior to impact, so the shaft by design is made stiffer to counter this effect. The opposite holds true as well. It only reasons that the manufacturers designed the graphite shafts to be more flexible to allow for the correct amount of flex at the longer assembly lengths they were intended for. This might be a very good reason why the manufacturers have produced softer shafts over the time than when we began our shaft-testing project. The "standard" length graphite-shafted Driver is longer than what it was 10 years ago.

As mentioned in Chapter 4, there was a certain category of shafts that were tested at different length - ultra-lightweight. These shafts were intended to be assembled at overlength assembles. As such, the lower frequency measurement was incorporated into the design. If we place the average frequency and torque measurements from our testing into the DSFI formula and adjust for the weight and length factors, we get the following results in Chart 7-11.

Chart 7-11 - Average DSFI Ratings for Ultra-lightweight Graphite Shafts

Flex	Frequency	Torque	DSFI
L	221	6.40°	71.11
A	230	5.76°	78.42
R	241	5.23°	83.77
S	257	4.77°	90.99
X	262	4.31°	94.66

All L-flex shafts measured at 44" and C-6 swingweight.
Men's flex shafts measured at 45" and D-1 swingweight.

The average DSFI for each flex in Chart 7-11 compares quite closely to heavier graphite shafts at shorter assembly lengths. The ultra-lightweight shafts possessed frequencies that are 10-16 cpm lower than traditional weight graphite and torque readings that are 0.7° higher. This example was shown to illustrate how frequency, torque and length interact to one another.

The other reason why graphite is perhaps to be more flexible than steel, may be the fact for whom graphite shafts were designed. The whole purpose of developing graphite shafts was to reduce the overall weight of the club in order to allow the golfer the ability to potentially swing the club faster. While graphite shafts have been produced to mimic the weight of standard weight steel and as low as 50 grams or less, the majority of graphite shafts are designed much lighter than steel. Understanding what shaft weight range a golfer should use is based primarily on the tempo of the golfer's swing, which leads us to our next topic.

Golf is a game of precision, in such that the timing is critical if the golfer wants to make contact with the ball with a square face. The timing of the swing is directly attributed to the weight and balance of the golf club. Golfers who are "hitters" need additional weight in the golf club to resist swinging too quickly. The lighter shafts benefit golfers whose transition from backswing to downswing is more rhythmic. Thus the golfer that is more rhythmic places less load or deflection on the shaft than a hitter would do with the same swing speed, so the shaft would not need to be quite as stiff.

This leads to a unique situation. The DSFI was initially designed to narrow down the selection of shafts to a more finite number, rather than the wide ranges the manufacturer's had suggested in their fitting charts. However, if two golfers who have the same swing speed, yet one swings the club with a slower tempo than the other, then shouldn't each golfer use a different shaft? The answer is yes. Remember the DSFI is an index number and not an absolute mph measurement, rather it is a starting point or minimal swing speed from which to start out with.

In the initial release of the DSFI, we had set up different categories for which clubmakers to choose shafts for their customers. The first was the Low Risk / Low Yield category, which would provide the golfer with the greatest accuracy. The speculation was one would choose a shaft with a DSFI very close to the actual swing of the golfer. The next category was High Risk / High Yield which one would choose a more flexible shaft that will yield more distance, but would have more risk associated with it. The clubmaker would choose a shaft that had a DSFI of 88% of the golfer's actual swing speed. The last category was the Moderate Risk / Moderate Yield which fell between the other two categories. Additional distance could be attained, but not as much accuracy loss was possible compared to the High Risk / High Yield. In this case, a golfer would choose a shaft with a DSFI somewhere between 88 - 100% of the golfer's actual swing speed.

While this became an integral part of the DSFI at the beginning, we received feedback from customers that the promise of added distance or greater accuracy did not always come to fruition. Eventually, we came to the realization in what we were attempting to do, was identify the tempo of the golfer. The golfer who realized the distance increase were golfers who possessed a slow swing tempo, while the golfer who was more of a "hitter" was better off finding a shaft closer to his or her swing speed.

While attempting to narrow the shaft selection to a specific swing speed range, it became apparent that many players, depending on how they swung the club, could use a particular shaft. The other factor that would affect the shaft decision making process is the length of the swing arc. The shorter the swing arc, the less time the shaft has to recover at impact. Therefore, the shorter swing arc a golfer possesses, the stiffer shaft is required. Thus, the DSFI was set up to find an acceptable swing speed range based on the tempo and length of the golfer's swing.

There are five categories to choose from in order to find an acceptable DSFI range. The first three are based on a full swing, while the last two are on partial swings. The first category is the most common among average golfers: the fast tempo / full swing. When referring to the type of tempo, it is the transition from back swing to forward swing that should be of utmost importance. The fast tempo golfer places a tremendous amount of stress on the shaft in the initial downswing. The golfer is placing an emphasis on acceleration at the top of the swing, rather than at impact. Therefore, the golfer needs a shaft with a DSFI close to his or her swing speed. Examples of this type of swing would be Nick Price and Lanny Watkins.

The next category, slow tempo / full swing, needs a shaft that is more flexible than one would think based on a player's swing speed. With a slow tempo, the golfer gradually builds up speeds and places very little stress on the initial part of the down swing. Examples of this type of swing are Fred Couples, Ernie Els and Bob Murphy. The moderate tempo / full swing, falls somewhere between the two categories mentioned before. Therefore the golfer will need a shaft with a slightly lower DSFI rating than their swing speed.

A partial swing in which the golfer takes the club back to less than parallel, will require a slightly stiffer shaft than the swing speed would indicate. The shaft simply doesn't have the time to recover as if the golfer had taken the club further back. This situation occurs as a golfer becomes older and less flexible. In some cases, the partial swing is the method in which they become accustomed to swinging the club.

The last category is the partial swing with no wrist cock, or in other terms, an all-arm swing. There are a number of women or newcomers to the game that fall into this category. This type of golfer will need a shaft with a much higher DSFI rating than their swing speed for two reasons. By not utilizing the wrist, the swing arc is extremely short. As noted before, the shorter the swing, the stiffer the shaft is required. Second, over time with proper lessons, the golfer may develop a wrist cock, which will automatically increase the swing speed generated by the golfer. By choosing a shaft that it much stiffer to begin with will fit the golfer for both the present and perhaps the future.

The factors for tempo and length of the golfer's swing can be found in the accompanying Shaft Fitting Addendum, located in the Procedural Outline. It should also be noted that shaft weight and tempo are interrelated. A golfer with a slower tempo is capable of swinging a club with a lighter weight shaft. The quicker the tempo by a golfer, needs additional shaft weight to help control swinging too hard during the initial down swing.

Other Factors that Influence DSFI Rating

Realizing that not all golfers will utilize the same length and swingweight as the shafts tested in our study, other factors had to be introduced into the system. The first of which is swingweight. As swingweight becomes heavier than D-1 for the men's flex shafts and C-6 for the ladies flex shaft, the club will become more flexible. The opposite holds true for clubs with a lighter swingweight. This is accurate as long as the change of swingweight is due to a change in head weight.

There are a number of grips that vary in weight between 35 and 80 grams that are commonly used on golf clubs. The heavier grip counterbalances the swingweight, but does not have an effect on the stiffness of the shaft. Only the addition or subtraction of head weight will cause a change to the swingweight, frequency and eventually the DSFI of the shaft.

How much change in swingweight will affect the DSFI of a shaft? To put this in perspective, a 1 swingweight point increase will change the frequency by only 1 cpm. If the industry average for frequency is 10 cpm between each flex, then a one swingweight point change would only amount to 1/10th of a flex. Subsequently there would be very little difference to the DSFI. Therefore, it would take an increase or decrease of 5 swingweight points to have any appreciable affect on the performance of the club.

The amount of tip trimming increase or decrease could also have an effect on the DSFI of a shaft. Regarding steel shafts, shafts that are made from an R&S combination flex are separated by approximately 10 cpm, 0.2º of torque and DSFI rating of 5-6. In proper circumstances, shafts can be trimmed in-between flex to further fine-tune the fitting process. Graphite shaft possibly could be trimmed more or less than what is suggested by the manufacturer. However, graphite is less predictable on how much of a change will occur by altering the tip trimming. Lastly, graphite shafts generally have shorter parallel tip sections, which can limit the amount of additional tip trimming that is possible.

For a full step-by-step outline on how to use the Dynacraft Shaft Fitting Index, you can reference the Procedure Outline pages in the Shaft Fitting Addendum. The Shaft Fitting Addendum can be downloaded off Dynacraft's web site at dynacraftgolf.com.

Conclusion

Since 1992, the DSFI system has been used by more clubmakers than any other system currently available. Each year we try to find ways to improve upon the system to allow clubmakers and golfers alike, to find shafts that are compatible to their game. Why this system works is simple. This study is based on actual testing performed under the same, precise testing conditions. For the first time, shaft specifications are standardized to provide real data that can be used to fit golfers worldwide.

We know as we move into the 21st centrurye know we have more work to do in order to fully understand how the shaft and each individual shaft parameter functions. Such testing will continue to go on in the upcoming years. Shaft fittingwill hopefully become a more simplified and accurate process as the future unfolds. This study, the first of its kind in the industry, is just the start.