Mitchell®
GOLF EQUIPMENT COMPANY

Loft, Lie & Face Angles

Measuring - Bending

REFERENCE

INTRODUCTION

Mitchell® Golf is delighted to provide this brochure to industry professionals. Our goal is to explain the proper way to measure the angles of a golf club and demonstrate the best bending techniques. In so doing, we want you to become comfortable and confident in your skills.

It is industry professionals like you that will carry on the tradition of enhancing the game of golf. We commend you for being part of this great game.

MEASURING ANGLES

The golf industry has struggled over the years in recognizing the proper measuring methods to determine golf club angles. In the past manufacturers have generally claimed that only they can measure their club's angles because they have their own proprietary method.

Today, however major club manufacturers recognize the measuring and bending capability of Mitchell® Angle Machines and accept industry professionals using Mitchell® Angle Machines to adjust their golf clubs. As a matter of fact, they all have Mitchell® Angle Machines either on their production line or in their tour departments as well as their tour vans.

Several years ago a well known component company developed a club head registration method that defies mathematics and repeatability. Their claim that a club must be measured in a specification gauge, then bent in a bending device and re-checked in the specification gauge is founded on a theory that has created confusion and frustration among industry professionals for years.

The specification gauge disciples in the golf industry have long advocated the only way to measure club angles is by placing the club head on its sole center (defined by the middle of the score lines) on the base of the specification gauge. That method at best is subjective to the eye and practically impossible to repeat. The fact is the golf ball is struck on the club's face, not on its sole.

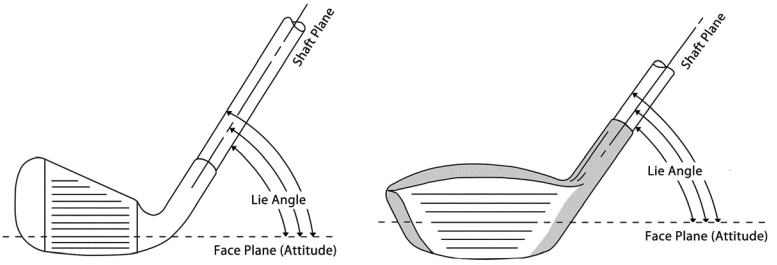
Therefore, the proper geometric measurement for loft, lie & face angles is to register the club's face attitude in a square and horizontal plane to precisely measure the club's angles in relation to the shaft plane. The ideal method is to register the club's score lines to a known square relationship to the measuring gauges. This allows for accuracy and repeatability. It becomes the benchmark for comparing lie angle marks on irons produced from an impact board. The angles displayed on the bending machine gauge become relative to any adjustment required and are not used to determine if the manufacturers specifications are accurate or not.

After proper registration in the bending machine clubs can then be adjusted to fit the individual needs of golfers allowing for game improvement while creating customer service profits for golf industry professionals.

It is commonly agreed the accuracy and bending capability of Mitchell® Angle Machines set the industry standard for aftermarket club adjustment and fitting.

LIE ANGLE

Lie angle is the angle formed between the shaft plane and the horizontal face plane (attitude), as shown in the following illustrations.

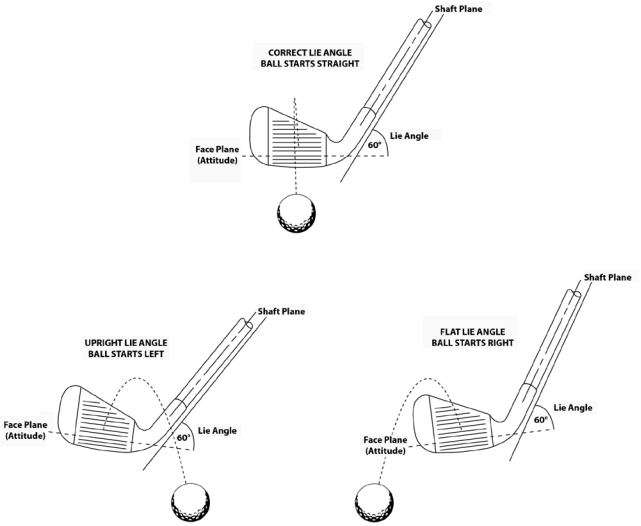


Irons, Metal Woods & Hybrids

Geometric Requirements For Club Head Registration

1. Club Head must be in horizontal face plane (attitude) with score lines parallel to registration device regardless of sole radius.
2. Club face must be square.
3. Lie angle is measured from the shaft plane to the horizontal face plane (attitude).
4. Lie angles are constant when measured from any parallel plane:
    - Inside edge of shaft
    - Outside edge of shaft
    - Center line of shaft
    - Extension of horizontal face plane (attitude)
    - Extension of shaft plane

Ball Flight



Lie is a primary influence on ball direction. Incorrect lie angles force the golfer to adjust or make swing compensations to overcome misdirected ball flight that is, in effect, built into the set of clubs.

Lie Marks

To determine the correct lie angle for a golfer use sole impact label and have the golfer strike golf shots from a lie board. The lie mark's position and shape made on the impact label is also an indicator of the club's face attitude at impact.

The lie is accurate when the center of the mark is centered toe-to-heel and slightly off the leading edge. This type of mark will result in a ball flight toward the target with very little sidespin.

As the face angle moves from closed to open, the mark will move from the leading edge toward the trailing edge, and from toe toward the heel.

Face Closed

Face Square

Face Open

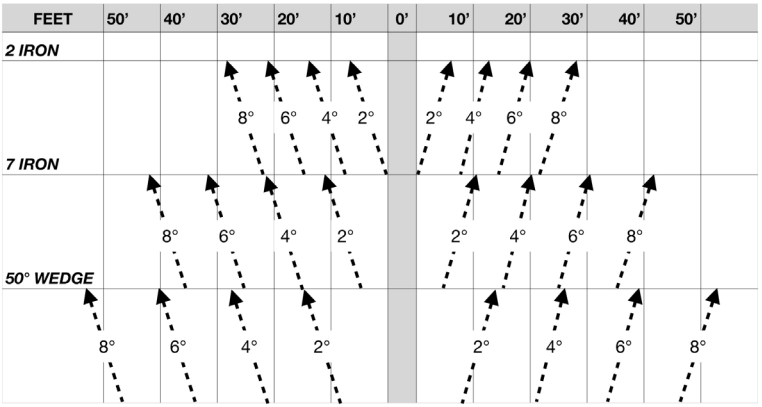
The greater the loft of a club, the more influence lie angle has on ball direction. Incorrect lie angles will start the ball more offline in higher lofted clubs, such as wedges, than it will in lower lofted clubs, such as drivers. As a ball spins after being struck, any directional problems will be exaggerated due to this spin in the "wrong" direction.

Thus, when fitting irons, especially shorter irons, lie is a critical factor in ball direction. When fitting drivers, lie is less of a factor due to the club's lower loft.

Lie angles that are "off" by just a degree or two can cause directional inconsistencies of a couple of yards. This becomes critical when hitting shots to a very specific target such as a flagstick on a green. The first place to look at irons to improve directional control is to look at lie angle.

DIRECTIONAL DISPLACEMENT LIE ANGLE CHART

Club #	Deviation From Straight Ahead					Directional Displacement				
	2°	4°	6°	8°	10°	2°	4°	6°	8°	10°
2 - 17° 200 yds	.61°	1.22°	1.83°	2.44°	3.04°	6.4°	12.8°	19.2°	25.5°	31.9°
3 - 20° 190 yds	.73°	1.45°	2.18°	2.90°	3.62°	7.2°	14.5°	21.7°	28.9°	36.0°
4 - 23° 180 yds	.85°	1.70°	2.54°	3.38°	4.22°	8.0°	16.0°	24.0°	31.9°	39.8°
5 - 26° 170 yds	.98°	1.95°	2.92°	3.88°	4.82°	8.7°	17.4°	26.0°	34.6°	43.2°
6 - 30° 160 yds	1.15°	2.31°	3.45°	4.59°	5.73°	9.7°	19.3°	29.0°	38.6°	48.1°
7 - 34° 150 yds	1.35°	2.69°	4.03°	5.36°	6.68°	10.6°	21.2°	31.7°	42.2°	52.7°
8 - 38° 140 yds	1.56°	3.12°	4.67°	6.21°	7.73°	11.5°	22.9°	34.3°	45.7°	57.0°
9 - 42° 130 yds	1.80°	3.59°	5.38°	7.14°	8.89°	12.3°	24.5°	36.7°	48.9°	61.0°
PW - 46° 120 yds	2.07°	4.13°	6.18°	8.20°	10.19°	13.0°	26.0°	39.0°	51.9°	64.7°
SW STG - 50° 110 yds	2.38°	4.75°	7.10°	9.42°	11.69°	13.7°	27.4°	41.1°	54.7°	68.3°
SW MID - 55° 100 yds	2.85°	5.69°	8.49°	11.24°	13.93°	15.0°	29.9°	44.8°	59.6°	74.4°



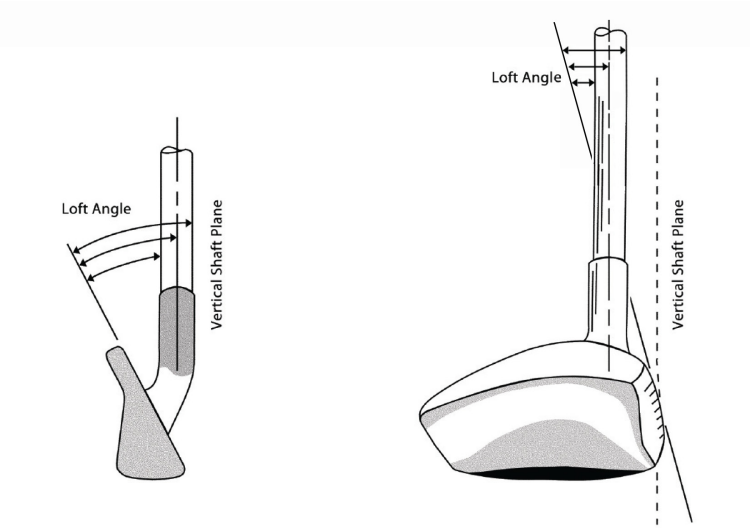
Produced By Henry-Griffitts

The lie of nearly all irons can be changed to match a player's swing characteristics. Measuring and changing lie angle to match a player's swing is among the first club performance specification factors to look at when dealing with irons. The time and expense of a lie angle change to an iron is well worth the payoff in directional performance improvement.

There are no industry standards for lie angles. The player's performance is the best indicator of correct lie angles. When the term "standard" is used for lie angle, very often the actual degree number that one company uses for the same iron will be different from another's. Therefore, refer to lie angles of clubs in terms of "degrees" (whole numbers) and not as "standard," "flat," or "upright."

LOFT ANGLE

The loft angle is formed by the vertical shaft plane and the pitch of the face as shown in the following illustrations.



Irons

Geometric Requirements For Club Head Registration

1. Club Head must be in horizontal face plane (attitude) with score lines parallel to registration device regardless of sole radius.
2. Club face must be square.
3. Loft angle is measured off the shaft plane to the pitch of the horizontal face plane (attitude).
4. Loft angles are constant when measured from any parallel plane:
   - Inside edge of shaft
   - Outside edge of shaft
   - Center line of shaft
   - Extension of horizontal face plane (attitude)
   - Extension of shaft plane

NOTE: *The vertical shaft plane on irons will always be square to the club's face plane.*

The goal of iron performance is consistent distance. It is important to set the lofts of the irons so there are uniform distances between each club in the set. As mentioned previously, there are no uniform standards in the industry; it is possible before adjustment to have more than one club in a set that hits the ball similar distances. Also, manufacturing tolerances (generally +/– 1-degree) often bring two clubs very close in actual loft. Gapping the irons is a performance upgrade that should be done to every set.

Metal Woods & Hybrids

Geometric Requirements For Club Head Registration

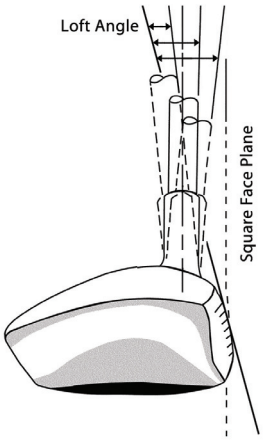
1. Club Head must be in horizontal face plane (attitude) with score lines parallel to registration device regardless of sole radius.
2. Club face must be square and centered to allow for the bulge and roll of the face.
3. Loft angle is measured off the shaft plane to the pitch of the horizontal face plane (attitude).
4. Loft angles are constant when measured from any parallel plane:
   - Inside edge of shaft
   - Outside edge of shaft
   - Center line of shaft
   - Extension of horizontal face plane (attitude)
   - Extension of shaft plane

NOTE: *On woods and hybrids, the face pitch is the plane intersecting the center of the face. The vertical shaft plane may not be square to the club's face plane.*

PLAYING LOFT

Club designers generally design the loft (face pitch) of metal woods and hybrids to the sole angle of the club head. However, based on design features such as location of center of gravity, club manufacturers sometime find it necessary to build in closed face angles for performance reasons.

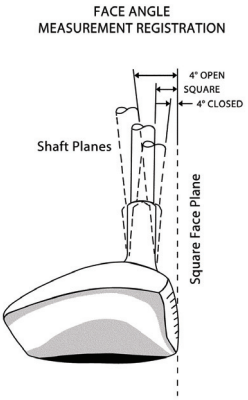
Face angles directly effect the playing loft of metal woods and hybrids.



When the shaft plane is not square to the face plane, the playing loft will vary. An open face angle will have less playing loft, a closed face angle more playing loft and a square face angle will be equal to the loft of the club. It can generally be stated that the playing loft relationship is one-to-one when comparing face angles to the pitch of the face to the sole. Example is a 9.5° driver will play more like 8.5° if the face angle is 1° open and 11.5° if 2° closed.

FACE ANGLE

When registered in a proper measuring device, face angle is the angle formed by the vertical shaft plane to the square face plane with no sole influence. Note: A proper measuring devise clamps the club head & and not the shaft as specification gauges do.



Metal Woods & Hybrids

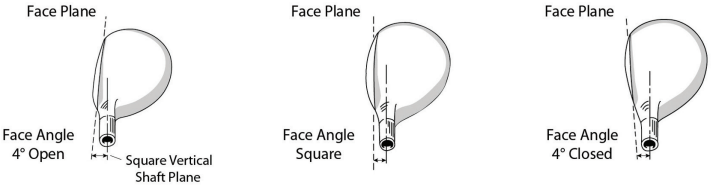
Geometric Requirements For Club Head Registration

1. Club Head must be in horizontal face plane (attitude) with score lines parallel to registration device regardless of sole radius.
2. Club face must be square and centered to allow for the bulge and roll of the face.
3. Face angle is measured off the shaft plane to the square horizontal face plane (attitude).
4. Face angles are constant when measured from any parallel plane:
   - Inside edge of shaft
   - Outside edge of shaft
   - Center line of shaft
   - Extension of horizontal face plane (attitude)
   - Extension of shaft plane

NOTE: *On woods and hybrids, the face angle is the relationship of the shaft plane to the face plane.*

When viewed in a playing position, face angle is the angle formed by the club's face plane (open, square, or closed) to the square vertical shaft plane when the club head is soled in its natural lie angle position.

FACE ANGLES PLAYING POSITION



Face angles on woods and hybrids have an effect on ball flight similar to the effect of lie angle. Assuming an on-plane swing, if the face angle is closed, the ball will fly left with a higher playing loft. If the face angle is open, the ball will fly right with a lower playing loft.

BENDING GOLF CLUBS: FACTS & FALLACIES

An Industry Professional's Guide To Angle Adjustments

As an industry professional you know that angle bending is among the fastest ways to improve a player's ball flight. Whether changing the lie to improve accuracy or changing loft to make certain that the player's clubs are progressively consistent, angle bending is a major factor in club performance. When it comes to loft, lie and face angles many players have incorrect ideas about what can be done and what effect changes may have on playability. Being an industry professional, it is important to become knowledgeable of all facets of club bending. When you do so, you become the equipment expert and your golfers will rely on you as their source of equipment alteration. Here are some facts and fallacies for you to be aware of so you can better serve the needs of your golfers.

Can cast clubs be bent?

Most irons can be bent, but the question of being able to bend cast clubs is still asked. The simple answer to that question is "yes". 17-4 stainless steel cast irons will be more difficult to bend since they are harder (C34-38 on the Rockwell Scale) than 431 (C18-25) or carbon steel heads (high B's on the Rockwell Scale).

Keep in mind that we are assuming the iron has the proper heat treatment and annealing that will permit bending. Annealing ensures a more consistent grain structure in the metal. Heat treatment makes the head hard enough to withstand constant golf ball impacts. Also, the club must have a hosel design that will allow bending. Special bars may be required for certain hosel designs such as those with a shorter hosel. With proper equipment nearly all hosel designs can be bent accurately and consistently ensuring properly fitted clubs for your golfers.

There is also a misconception that clubs have "memory" which makes them naturally return to the original specification after bending. This is simply not true. Once a club is bent to a given specification it will stay there until changed by an outside force of either bending again or striking a hard object. Loft, lie and face angle changes are more or less permanent.

Can today's metal woods be bent?

Even though a lot of people will immediately say no, the correct answer is "yes" with certain requirements. While there are limitations, many of today's metal woods are indeed bendable, especially stainless steel heads. Forged titanium models are bendable as well. Their softer titanium structure allows bending. Provided the hosel of the wood is long enough to allow the bending bar to fit over its length, metal woods can be bent to custom fit a player. This applies to both lie and face angle.

What about bending the loft of a metal wood? When you bend the hosel toward or away from the face plane you open or close the club's face angle. This will change the playing loft of the club by changing the trajectory of the ball but it will potentially cause misdirected shots. Don't be misled that tour professionals de-loft their drivers and get more distance.

Do club companies manufacture progressively consistent clubs?

In short the answer is "no". While they certainly try to make consistent product, they do not necessarily do so. It would be nice to believe that every set comes from the factory with precise specifications, but this is just not the case. There are often inconsistencies in the lofts and lies of the clubs. Clubs are mass-produced with certain +/-manufacturing tolerances in every factory. However, you can easily bend the lofts and lies to be progressively consistent from one club to the next with zero tolerance. Plus you can bend the angles to a consistent specification precisely fit for any golfer.

Are there standards for loft, lie & face angles?

One of the most overused words in the golf industry is "Standard." Instead of the word standard, perhaps the word average should be used. Or maybe no word should be used.

A quick look on the internet at specifications for the best selling #5 irons from four major manufacturers shows lie angles of 60, 60.5, 60.75 & 62 degrees. Not surprisingly there is no stated tolerance on any site, making one wonder just how close that 60.75-degree specification is. A look at standard lofts of #5 irons from these same manufacturers shows that two use 27 degrees while one is at 26 and one at 25.

As an industry professional you should use the manufacturer's specifications as a reference only. When adjusting loft ask the player if they have any distance gaps between clubs that a loft change of a degree or two will correct.

The word standard really doesn't come into play with club performance fitting. Each player should be matched to his or her own individual specifications. If you want to call those specifications standard for that player, fine. But make sure you record the details for future reference, thereby setting their "standard" for improved individual performance.

It is vital to know the exact specification of the club's angles when checking for a proper fit using a lie board test. The lie board test could show the need for the club to be more upright or flatter. The performance is the key element during the lie test, which determines a specific angle in degrees. The test club must be measured and adjusted to the new angle. Remember the set is not necessarily progressively consistent and therefore each club should be bent to a predetermined angle in relation to the test club. Do not bend every club in the set by the proverbial "2 degrees up or flat" thinking you adjusted the entire set consistently.

How does bending influence bounce?

Any change in a club's loft will correspondingly change the club's bounce. The relationship is one-to-one. As you decrease the loft of a club by one degree, you reduce its bounce a degree at the same time. The bounce angle increases equal to the amount of any loft increase. A one or two degree change in loft will not cause a bounce or dig sole with today's clubs. But if you are changing lofts on older more flatter-soled irons, bounce should be taken into account.
If you do change the loft more than two degrees on a club, sole grinding may be necessary to restore the sole angle to a more playable position. Changes in lie do not affect the bounce of a club in any manner.

Can you be sure that a club will not break during bending?

Even the most skilled repair professionals can occasionally break a club. Generally breakage is a result of some type of inconsistency in the metallurgy of the club. Cast clubs may have voids in their internal structure. These voids are effectively weak spots that when subjected to pressure from bending will often cause hosel breakage. In addition the club may not have been heat-treated properly and can be very brittle. The hosel of the iron may have been bored off-center resulting in an inconsistent hosel wall thickness. Breakage can occur when bending pressure is applied to the thinner hosel area. None of these manufacturing inconsistencies can be identified prior to bending.

A properly manufactured club may be bent many times without breaking. There is no worry about bending a club that was bent last year or last week. It can be re-bent without any negative effect on it.

Proper Club Head Registration

Club head registration is the key element when bending or measuring clubs. Proper registration requires the club to be clamped securely in the bending machine with the face square and horizontal by positioning the club's score lines parallel to a horizontal reference point. Score lines are manufactured into the club's face parallel to the face attitude. The face attitude at impact is what directs the ball's flight.

The club's sole and its imaginary ground line have nothing to do with the attitude of the club's face at impact. Measuring the club's lie off the center of the club's sole in a specification gauge is impossible to do accurately and it is impossible to repeat the measurement. Loft and lie angles are accurately measured from the club's face attitude (horizontal score lines) to the shaft plane and are repeatable.

How much can a club be bent?

The common industry answer is "2 degrees." This limit is only recommended when changing the lofts on irons due to the potential effect such bends will have on the sole angle of the club. If the hosel design and manufacturing process allows, the lie of an iron can be bent 3-4 degrees or more with no compromise to the integrity of the head. This is especially true of clubs made with long hosels.

Practice on a few old irons in order to become comfortable in bending lie more than 2 degrees. It is easy to do in a machine that securely holds the club. Machines without adjustable sole clamps will often allow the iron to slip during bending, making the repair professional think the club bent when it didn't.

Metallurgy

The Rockwell Hardness Scale uses an alpha-numeric designation to compare different metals. The Rockwell Scale, developed in conjunction with the ASTM (American Society for Testing and Materials) is the most often used measure of metal hardness in the world today. The higher the alpha-numeric designation, the harder the metal; "C" is harder than "B", "30" is harder than "20". Aluminum, for example is softer than stainless steel. Its Rockwell Hardness is in the B50-60 range, while stainless steel has a hardness in the mid-C range.

Material	Hardness	Primary Use
Aluminum	B50-60	Woods, Putter
Carbon Steel	B60-70	Irons, Putters
304 Stainless	B75	Irons Only
Beryllium Copper	B70-80	Irons, Putters
431 Stainless	C18-25	Irons, Putters
100% Titanium	C24-28	Woods
6-4 Titanium	C32-36	Woods, Faces
17-4 Stainless	C34-38	Woods, Irons, Putters
450 Steel (SuperSteel)	C36-40	Woods, Irons
15-5 Stainless	C36-44	Woods
Beta Titanium	C40+	Woods
Maraging Steel	C45-55	Woods, Faces

Irons

The vast majority of irons can be bent at least two degrees and in some cases as much as 3 or degrees. Metallurgy and hosel design are key factors in the bending of clubs. Irons are generally cast from either 431 or 17-4 stainless steel or are forged from any number of varieties of carbon steel. Stainless steel is harder than carbon steel, but both types of steels can be bent.

Irons made from zinc should not be bent. Zinc is a die cast material that breaks easily. Two easy ways to determine if a club is zinc include holding a magnet to it (zinc is non-magnetic, stainless and carbon steels are magnetic) and by looking at the hosel diameter. Zinc hosels are noticeably larger in diameter than are stainless or carbon steel iron hosels due to the brittle cast zinc material.

Hosel design also plays a part in iron bending. Shorter hosel irons can be bent, but they require a short hosel bending bar. The hosel crotch design of an iron influences its ease of bending as well. If the crotch is deeper, the club will generally bend easier.

Another consideration when bending irons is their finish. There are some irons on the market that have gunmetal black finishes. Black clubs tend to develop spiderweb cracks in the finish when the iron is bent. There is no structural damage to the head, but cosmetically the club is no longer pristine.

A similar factor applies when bending chrome plated irons. The metal of the iron will tend to bend easily, but some clubs today have a soft chrome plate and may mark when bent. Again, structurally the club is fine, but the cosmetics have been compromised.

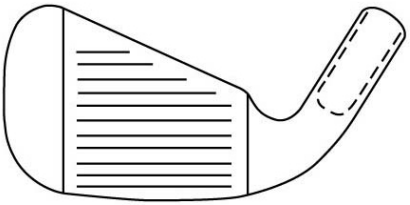
To Bend an Iron:

1. Measure current loft and lie angles of the iron.
2. Bend the iron to the desired angles.
3. Measure the iron to determine that the bends have been made correctly.

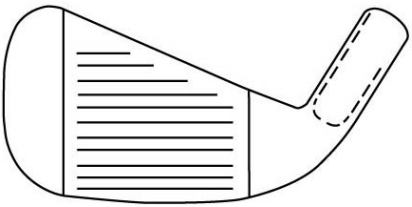
It is worth noting that as an iron is bent, there are effects on other club specifications. These include possible changes in bounce angle, offset, and swing weight. As a club is bent stronger, its bounce angle will decrease and its offset will increase. The bounce angle will change at a ratio of 1-degree of bounce change for 1-degree of loft change. Following the same ratio, when a club is made weaker, its bounce will increase and its offset will decrease.

Regarding swing weight, if a club's lie angle is adjusted approximately 3 degrees flatter, the swing weight will likely change 1-point. A club made more upright will swing weight less but the ratio of 3 degrees does not always hold true.

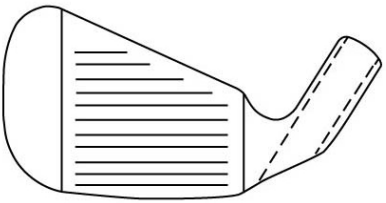
Hosel Designs:



Most friendly design
Bends up to 4° depending on material and Rockwell hardness
Little risk of cosmetic damage



Least friendly design
Bends up to 3° depending on material and Rockwell hardness
Bottom of bore at or below top line of club face
Hosel can form a flat spot or indentation blemish



Friendly design
Bends 3° without risking damage
At 4° bend – Risk causing small cracks at the bottom of the bore-through
May be necessary to blend the shaft tip to the sole using a buffing wheel.

Bending Technique:

1. Place bending bar as low as possible on hosel.
2. Adjust bending bar knuckle to snug fit on hosel.
3. In the direction of the desired bend, exert pressure on the bending bar to take out any torque.
4. Bend hosel with short "bumps" of pressure.
5. Bend hosel in plane with the shaft. (Parallel with side and front of the bending machine).

Metal Woods & Hybrids

Provided the hosel is long enough, polished, and the club head is made from stainless steel or forged titanium, lie and face angles can be changed. Loft, however, cannot be directly changed. Any change in a wood's face angle will alter its playing loft. If a club is made more open, it's playing loft is reduced; as its face is closed, it's playing loft increases.

This change is very close to a one-to-one relationship--that is, if a face angle is closed one degree, the club's playing loft is increased about one degree. Playing loft can be defined as the actual loft of the club at impact, as opposed to static loft, which is the club's designate loft by the manufacturer.

Related to wood bending, material and hosel length are the key. Stainless steel and forged titanium woods can be bent. Cast titanium models and those with hosels less than 1"-long are not candidates for bending. Obviously, no hosel designs cannot be bent. Even if the hosel is long enough to allow bending, if it is painted, the paint will likely be damaged during bending. Metal wood & hybrid bending follows the same principles as iron bending.

To Bend a Metal Wood or Hybrid:

1. Measure current lie and face angles of metal wood or hybrid.
2. Bend the metal wood or hybrid to the desired angles.
3. Measure the metal wood or hybrid to determine that the bends have been made correctly.

Bending Technique:

1. Place bending bar as high as possible on hosel.
2. Adjust bending bar knuckle to snug fit on hosel.
3. In the direction of the desired bend, exert pressure on the bending bar to take out any torque.
4. Bend hosel with short "bumps" of pressure.
5. Bend hosel in plane with the shaft. (Parallel with side and front of the bending machine).

CONCLUSION

Golf club manufacturers do not have to make precise nor consistent sets of club. They do, however, need to manufacture clubs with designs capable of being adjusted at the point of sale. The most important design requirements are satisfactory hosel length and shape; and metal hardness in cast clubs. It is important to point out that due to the investment cast process, cast club heads do not have precise and consistent angles as previously claimed. The fact is, cast clubs need angle adjustments in order to make a set progressively consistent.

The golf industry needs to embrace a different marketing tactic in reference to "standard" angles. Manufacturers have varying "standards." Therefore, when a golfer is recommended a 2° upright lie; the 2-degrees is upright from what? One manufacturer's 2° upright is not the same as another's. If the set is not checked to compare the progression of angles, how would the golfer know his set is progressively consistent at 2° upright.

Herein lies a serious flaw in club fitting. With the proper equipment, dynamic club fitting eliminates this flaw and allows the club fitter to adjust the lie angles to actual whole numbers, i.e., 62°, rather than just 2° upright. This should be done at the point of purchase by the club fitter so the golfer knows exactly what his club's angle performance numbers are. Club fitters can even be creative by adjusting the club's angles to enhance the golfer's shot making by adjusting for inconsistent performance of individual clubs in the set.

Golf club angles make a difference in club performance and influence how golfers swing the club.

LIE/LOFT ANGLES IRONS GUIDE

	Old Average			*Modern Average*			*New Modern Average*		
Club	***Loft***	***Lie***	***Length***	***Loft***	***Lie***	***Length***	***Loft***	***Lie***	***Length***
1 Iron	12	56	39	16	56	39.5	15	58.5	40
2 Iron	20	57	38.5	18	57	39	17	59	39.5
3 Iron	23	58	38	21	58	38.5	20	60	39
4 Iron	26	59	37.5	24	59	38	23	60.5	38.5
5 Iron	30	60	37	28	60	37.5	26	61	38
6 Iron	34	61	36.5	32	61	37	30	61.5	37.5
7 Iron	38	62	36	36	62	36.5	34	62	37
8 Iron	42	63	35.5	40	63	36	38	62.5	36.5
9 Iron	46	64	36	44	64	35.5	42	63	36
PW	50	64	35	48	64	35.5	46	63.5	35.5
SW	56	64	35	56	64	35.5	56	64	35

This is only a guide and does not represent a "standard" for all brands of golf clubs.
When clubs are "custom fitted" the specifications can vary.

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