Nathan Jarboe, P.E.
Schwaniger Enterprises
www.schwaniger.pro

Chainsaw Felling Spike Analysis
Stihl 500i Ti-DAWGS

The Stihl MS 500i chainsaw is becoming a popular professional use chainsaw for a variety of loggers, arborists, and others who desire a light weight yet powerful saw. The main selling point for the saw is that it monitors and injects fuel electronically into the crankcase via a fuel solenoid or fuel injector rather than mixing air and fuel in the traditional way through an old-fashioned carburetor. The saw has roughly 80 cc of displacement, so it is large enough to cut the heaviest of logs yet is light and maneuverable enough to offer versatility for limited limbing and other smaller tasks.

The saw is offered by Stihl with two basic model configurations – “500i” and “500i-R”. The saw shown in the image below is the standard 500i model. Shown is the standard handlebar, the smaller/shorter clutch cover, and smaller bumper spikes.

Figure 1 - 500i Basic Configuration

The second configuration is the 500i-R. This model is the same as the standard 500i with the addition of a wrap-around or "full wrap" handlebar, a larger clutch cover which extends further downward, and larger bumper spikes. The full wrap is designed for tree felling and bucking to offer more options for hand positioning while running the saw sideways. The larger spikes are used to help direct the saw while felling and bucking, to give more grip on logs with thicker bark, and to keep the logs and trees further from the operator's knuckles, muffler, and chain brake flag or "hand guard" to keep from activating the chain brake inadvertently.

Figure 2 - 500i-R with Full Wrap Handle, Larger Cover, and Larger Felling Dogs/Spikes

Purpose of Felling Spikes

Bumper spikes, or felling spikes, or felling dogs, may be used interchangeably and are hereto referred to as felling spikes. Felling spikes:

1) Prevent the saw from moving too close to the tree
2) Grip the wood and bark to allow the user to perform certain functions with the saw

Felling:

Cutting a tree down, or felling, can be done a few ways. A standard vertically standing tree typically requires some sort of notch to one side in the desired direction of fall, and a second large back cut. The back cut progresses toward the forward notch until a hinge is formed allowing the tree to fall in a controlled manner. The following photo shows a simple set of labeled cuts. Cuts take place in the order shown.

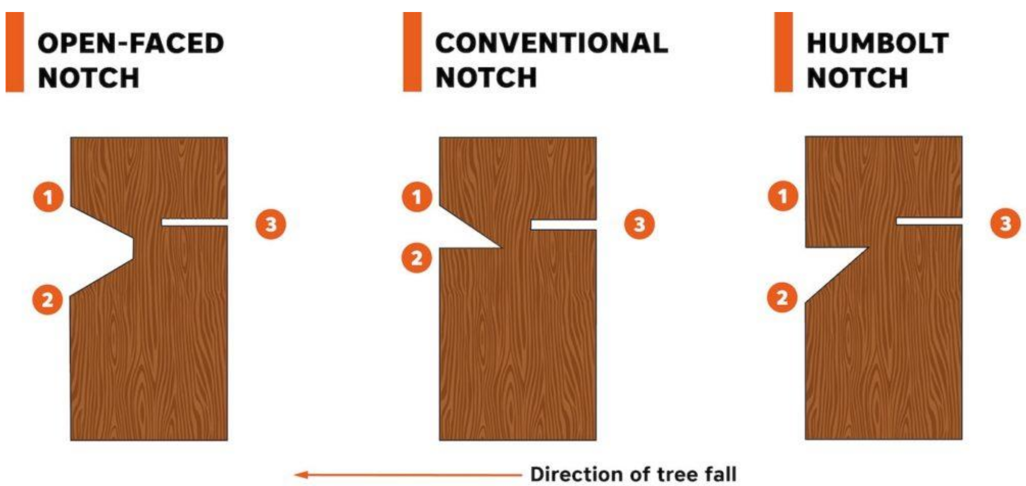

Figure 3 - Order of Cuts for Felling a Tree (Image from House Grail)

Figure 4 – Professional Employing Chainsaw Felling Dogs to Place Cut #2 in a Humbolt Notch
Felling Spikes are in Active Use for this Situation (Guilty of Treeson Image)
Operator Pushes Lightly Toward the Tree with his Left Hand While his Right Hand Pulls Back
Cuts #1 and #2 meet on Opposite Sides of the Tree for the Notch

Leverage, Chains, and Saw Forces/Moments:

The basic forces required for a chainsaw/operator system to cut a tree are summarized here.

Red arrows indicate forces due to pressure applied between saw teeth and tree and those which must be applied to the saw handles to counteract this. Blue arrows indicate thrust force on the saw due to the chain motion through the wood, and corresponding saw forces applied to balance these. Orange color is reserved for bumper spikes and corresponding reactions.

Figure 5 shows the case of cutting small limbs or logs with a saw. Shown are forces in the sense and direction which they act upon the saw. The top image, situation 1, shows "muscling" the saw which means applying forces to the handles to offset both the pressure applied for cutting and the thrust do to the moving chain. The lower image, situation 2, shows the situation where the saw is allowed to move forward toward the log until it contacts the spikes. In this case a force is applied to the spikes equal and opposite to that applied by the moving chain dragging across the wood. The saw is pulled forward into the wood, but the spikes rest or brace against the wood, relieving the operator of that set of forces (blue arrows). This reduces operator input and fatigue. For purposes of this analysis, this situation is referred to as "passive" use of the bucking spikes. The operator simply allows the saw to pull forward until contact is made, and the saw rests there as cutting takes place.

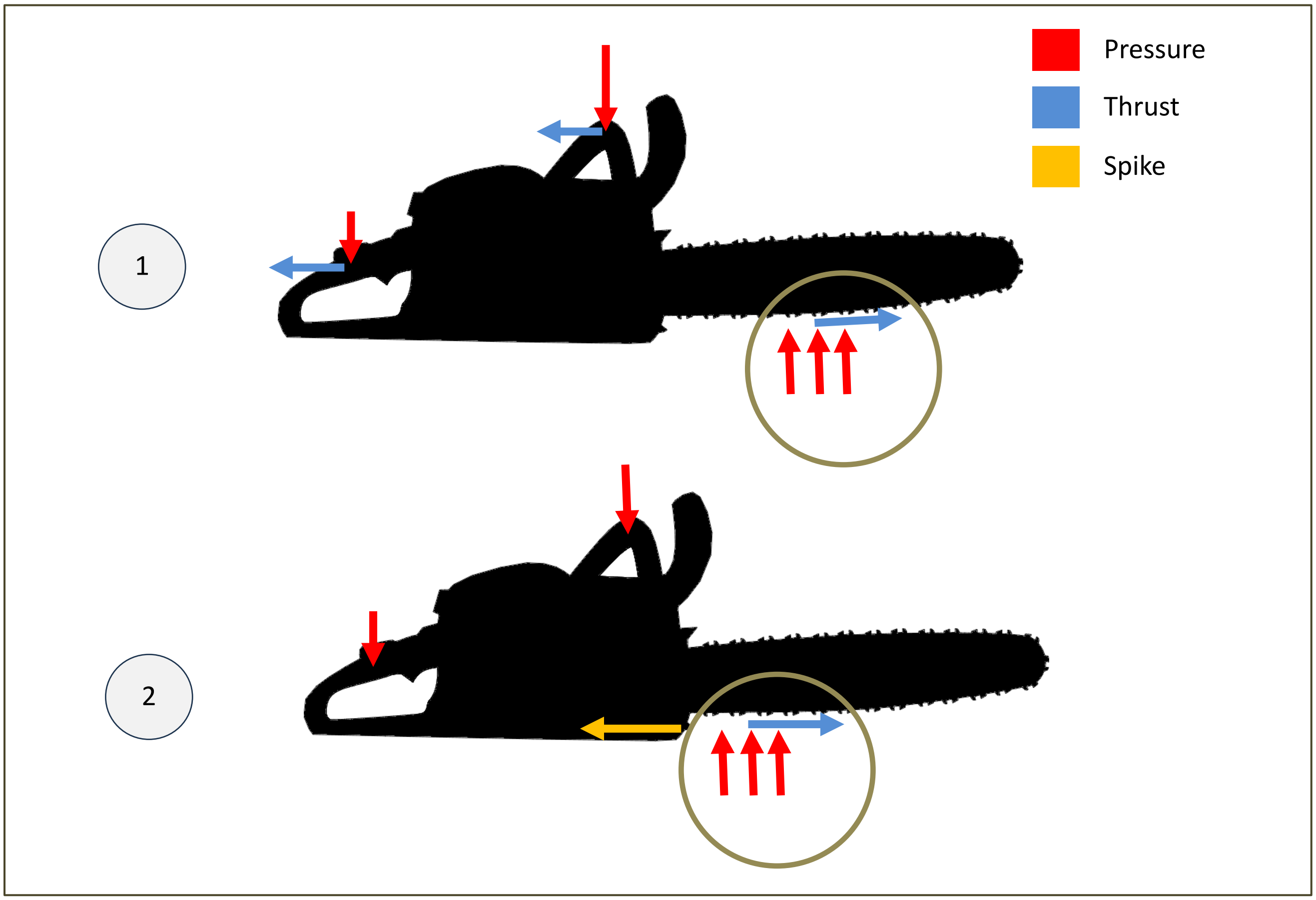

Figure 5 - Free Body Diagram of Chainsaw – Passive Use of Felling Spikes

Figure 6 is an attempt to demonstrate the essence of felling spikes. As can be seen in step 1, when the cut begins, slight pressure is applied to the front handle to keep the saw in contact with the tree. A force is applied in the opposite direction to the rear handle, pulling that end of the saw in a direction away from the tree. This would be counterintuitive if not for the presence of the felling spike in contact with the tree. The spike then becomes a fulcrum about which the saw is rotated to force it into the tree for the cut. Resultant rotational moment is indicated by the yellow arrow near the lower spike.

It is to be emphasized that felling spikes are not a substitute for a properly sharpened chain. On the contrary, a sharp chain reduces all forces necessary for an effective cut. All things being equal, a sharp chain causes less thrust because it cuts through the wood easier. Pressure on the cutting teeth and bar are also reduced by a sharp chain. Finally, a sharp chain reduces upward force on the rear handle required to rotate the saw into the cut. Operator input is reduced in all manner by a sharp chain.

Step 2 of Figure 6 shows repositioning of the saw in the cut. The spikes are then employed to rotate the saw again into the cut. The repositioning process has several advantages. For one, it forces the portion of the bar nearer the operator to do the cutting, which reduces the moment and forces required to rotate into the cut, which requires less input from the operator. Second, it reduces the surface area the chain is in contact with inside the cut, which naturally increases local pressure on each cutting tooth, further facilitating the production of chips through more localized pressure. Thirdly, reducing the overall length of cut the bar is in contact with facilitates removal of chips from the cut, which is more efficient since the teeth which follow behind each other are not forced to re-cut chips which have already been removed from the log only to carry them along inside the cut. Resultant rotational moment is indicated by the yellow arrow near the lower spike.

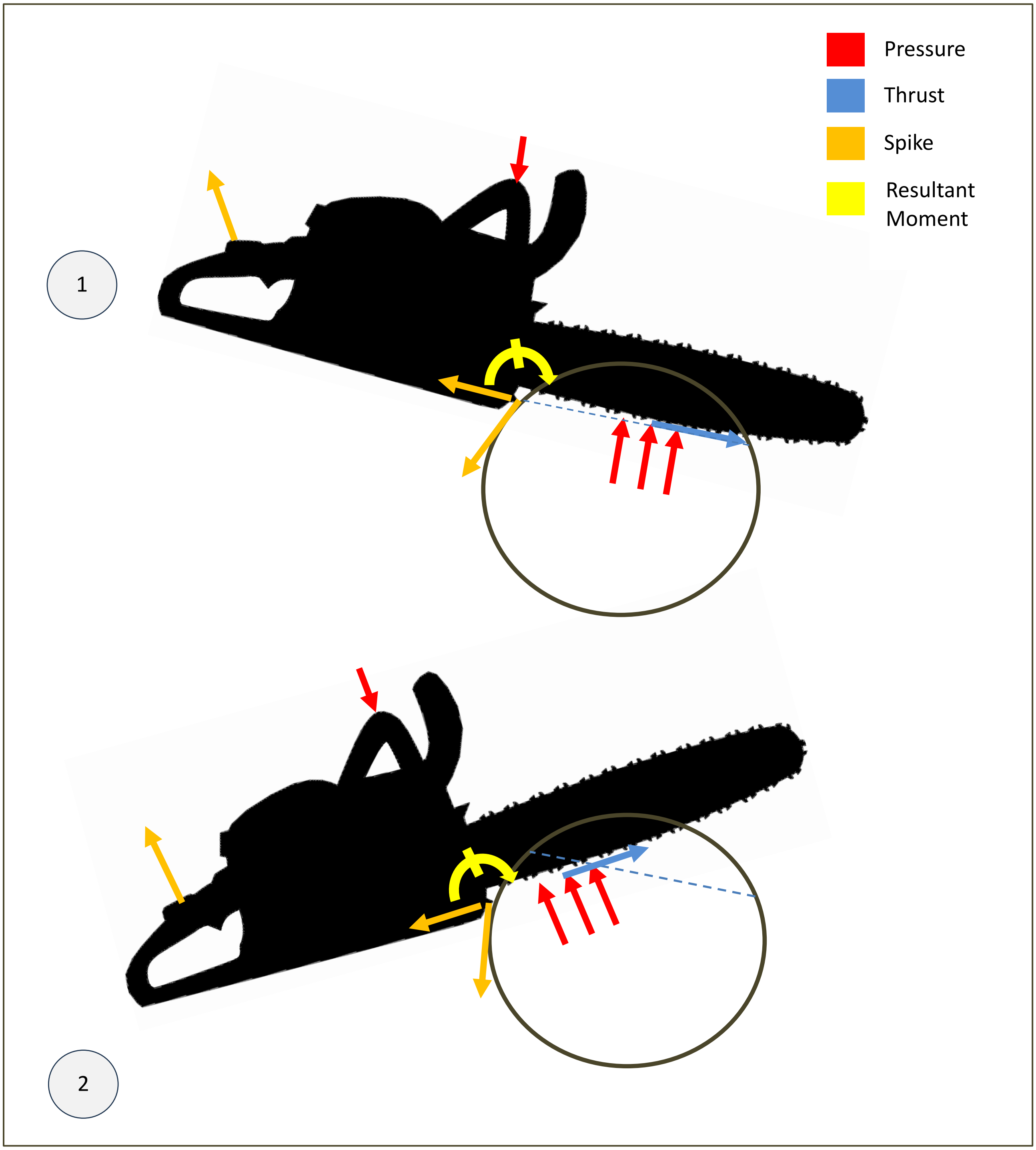

Figure 6 - Free Body Diagram of Chainsaw – Active Use of Felling Spikes

Figure 7 demonstrates more plainly that of Figure 6 without the additional arrows and colors. The dotted lines below the bar represent the cut region of wood which the saw has removed. Note that position 2 is a continuation of position 1 with the saw being repositioned slightly. Whether felling, bucking, or limbing, this process is employed in various ways depending upon the desired effect. Many factors play a part such as which portions of wood are in compression or tension, the desired direction on wishes the cut piece to fall, etc. This method is only possible with felling spikes which provide contact with the wood in a variety of positions, and which attain sufficient traction with the wood and/or bark to achieve proper purchase for effective manipulation.

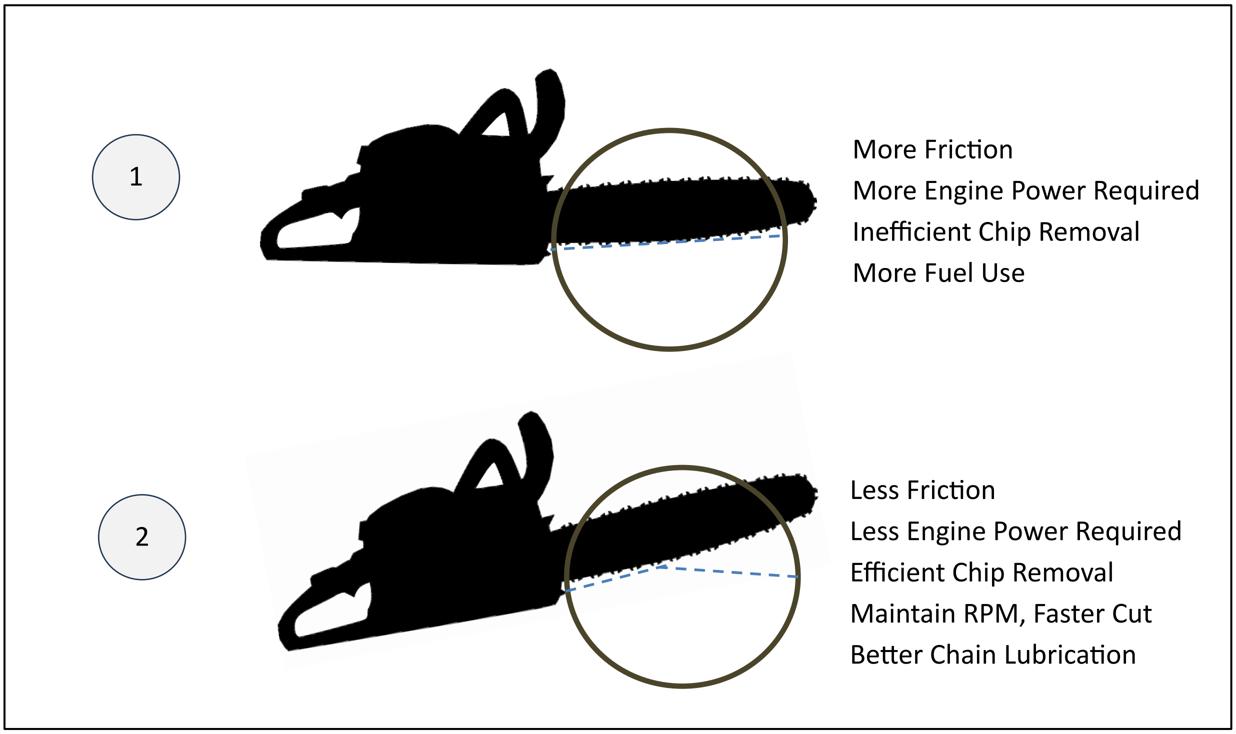

Figure 7 - Varying Angle of Cut for More Efficiency

Saw and hand protection:

Felling spikes with slightly more length help keep the saw spaced away from the wood during operation. This may have several advantages, as shown in Figure 8.

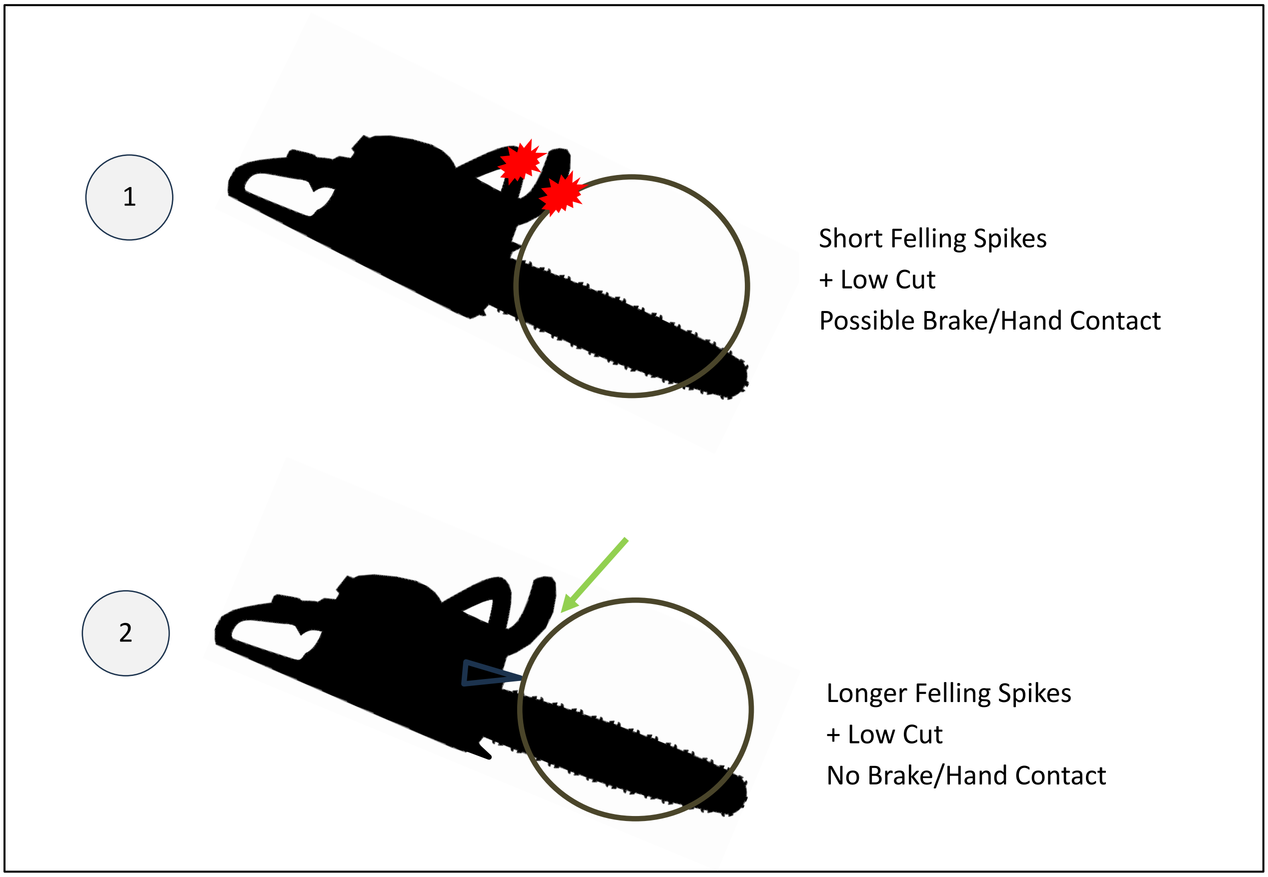

Figure 8 - Longer Spikes Mean More Space

Stihl Original Equipment Manufacturer (OEM) Bumper Spikes

The standard bumper spikes for Stihl 500i are likely adequate for the majority of users yet are found lacking by some. Made from what appears as stamped 0.100-thick relatively soft steel, coated with what appears a thin electroplated coating, and of a modest size, they offer a good compromise for Stihl with respect to function versus cost, and likely perform satisfactorily for many. However, they have shortcomings which will now be discussed.

Table 1 - Bumper Spike Part Numbers

OEM Bumper Spikes for MS 500i	
Part Number	Description
1142 664 0501	Bumper Spike - Outer
1142 664 0500	Bumper Spike - Inner

The table above lists bumper spike part numbers. Below are images of these bumper spikes which come standard on a 500i. Note the red circles. Red circles indicate regions with thinner and less bulky cross sections, which under hard use (or perhaps abuse) may yield and cause the spikes to bend out of position. It appears engineers at Stihl somewhat expected this, as evidenced by the formed sections shown at the bottom of each spike which stiffen the spikes in this region. Unfortunately, this formed or stamped-in feature does not continue all the way to the lower mounting screws, which still leaves the spike weak in the flatter region indicated just above the formed sections.

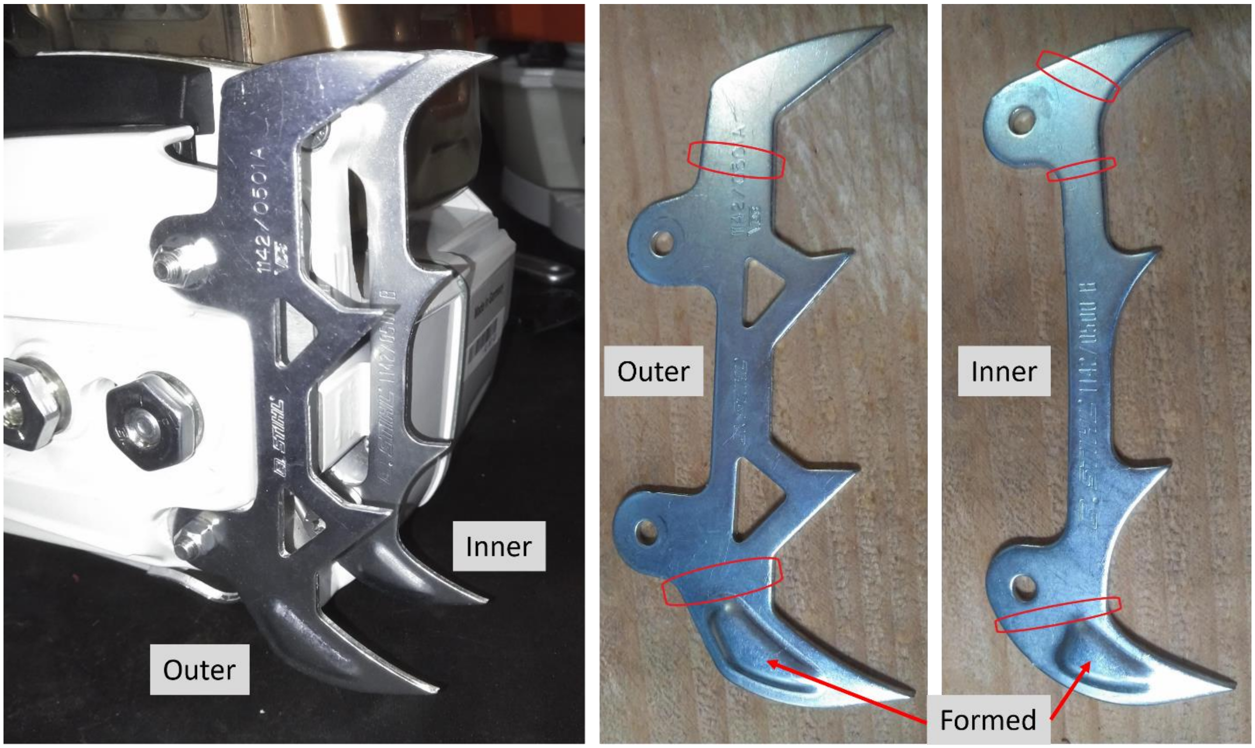

Figure 9 - OEM Bumper Spike Features with Noted High Stress Regions

Evidence of Spike Troubles in the Field

Several saws received into a Stihl authorized workshop were examined. One particularly dirty saw showed evidence of the statements made above. This saw showed obviously deformed bumper spike teeth in the regions indicated by red circles in the previous images. See photo below. This saw came in with obvious damage to the factory chain catcher, also, indicating the loose chain shown in the photo may have been a habit which caused frequent chain derailments.

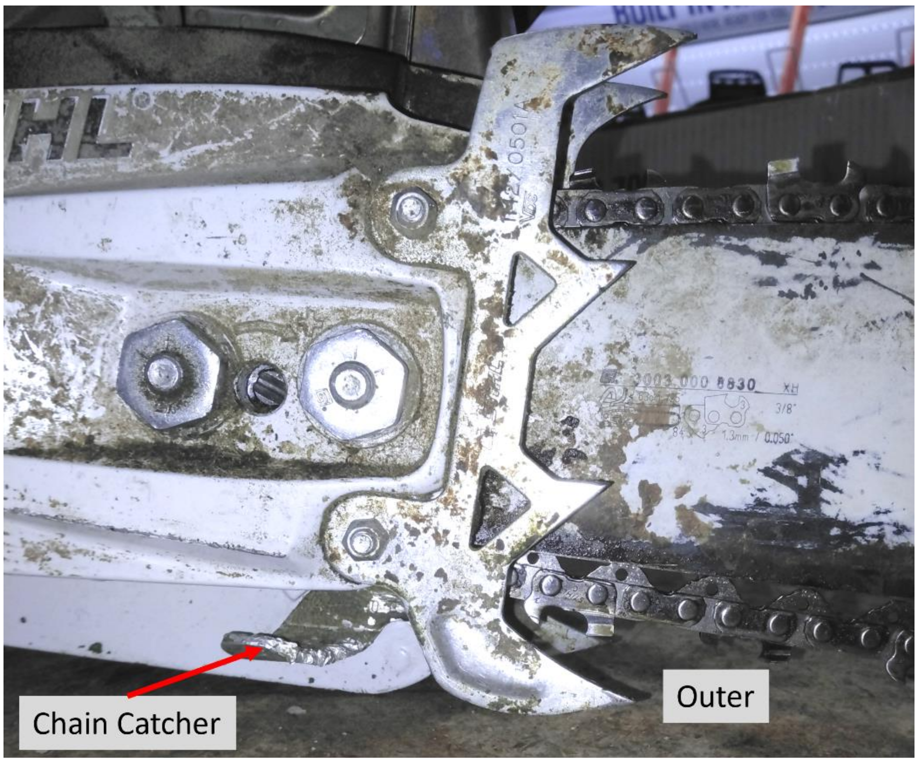

Figure 10 - Well-Used/Abused Non-Running Chain Saw in a Repair Shop

The next photo shows a bent lower bumper spike tooth on the outer bumper spike. See the white squarish indicator below.

Figure 11 - Close-Up of Bent OEM Felling Spike

A view from on top of the saw looking down shows each upper and lower bumper spike bent outward on both the outer and inner spikes.

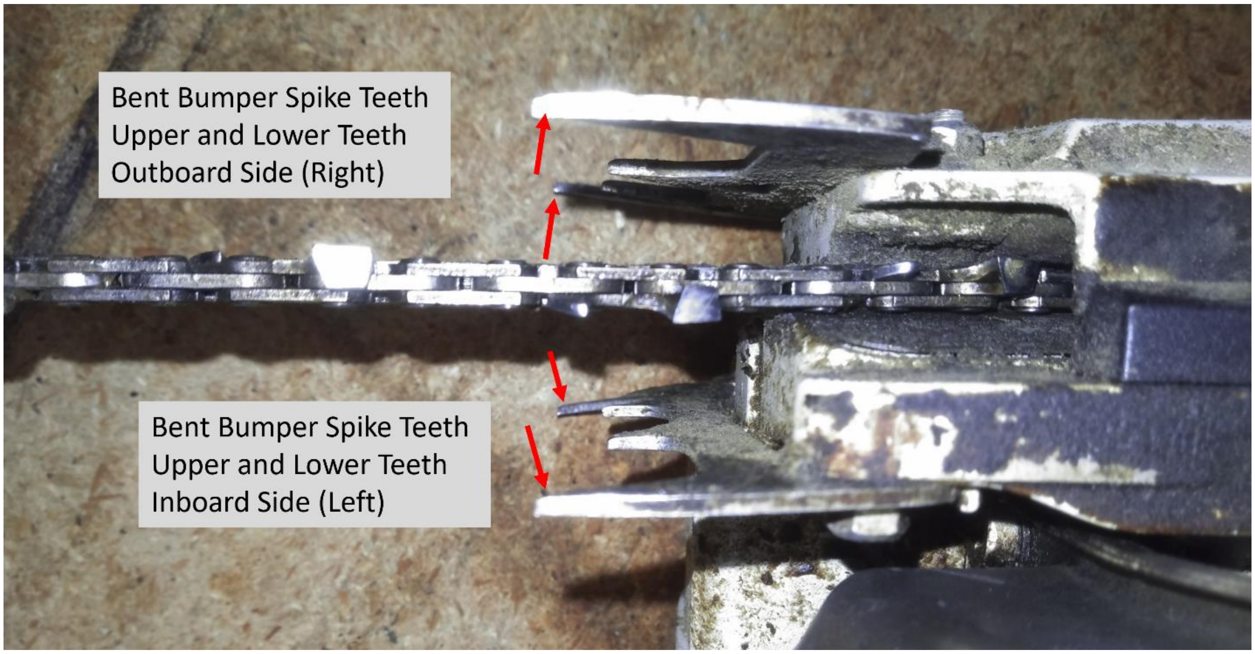

Figure 12 - Top View of Bent OEM Felling Spikes

Stress Analysis

An analysis of OEM bumper spike bending strength is conducted, and a comparative assesment is offered for the prototype titanium felling dog.

Materials:

It is unknown the exact material used to create the Stihl OEM bumper spikes. Formal material testing was not conducted - it is assumed a balance was struck between performance, weight, and most of all cost. The parts appear stamped, which is consistent with a large-scale mass-produced and low cost product. A36 mild steel, with yield strength of 36 ksi, is a probable material. A quick perusal of industry information related to material properties indiccates the parts are likely made of low carbon steel for cost and ease of formability, which also suggests a low-cost material. However, given the intended use and requirement for toughness, and to give the manfuacturer the benefit of the doubt, a slightly stronger material is assumed. HSLA (high strength low alloy steel) is another popular candidate for stamping, and Grade 945A is thus assumed.

Table 2 – Material Property Comparison

Material Properties		
Part	**Material**	**Yield Strength (psi)**
1142 664 0501 Outer Bumper Spike	SAE 945A HSLA Steel	42,000
Ti-DAWG Titanium Outer Bumper Spike	Grade 5 Titanium 6Al-4V	100,000

Appllied Force:

A sideward force is assumed applied to the tip of the lower bumper spike on the 1142 664 0501 outer bumper spike as shown below, as well as to the prototype titanium spike for comparison.

Figure 13 - Applied Abuse Load for Bending Analysis

Dimensions and Bending Sections:

Size Comparison:

The following figure shows the OEM outer spike overlaid upon the aftermarket titanium outer spike. The size difference both in spike placement and overall height is readily apparent.

Figure 14 - Felling Dog Size and Shape Comparison

Calculations which follow will focus on bending strength. Buckling and shear comparisons are expected to be similar. Basic spike dimensions with cross sectional measurements are shown below. Section A-A is compared between both spike styles. Sections B-B and C-C are also evaluated. Note that section B-B is conservative, because in actual service a bolt with nut is installed in the hole and torqued, which helps transfer bending stress across the hole at section B-B.

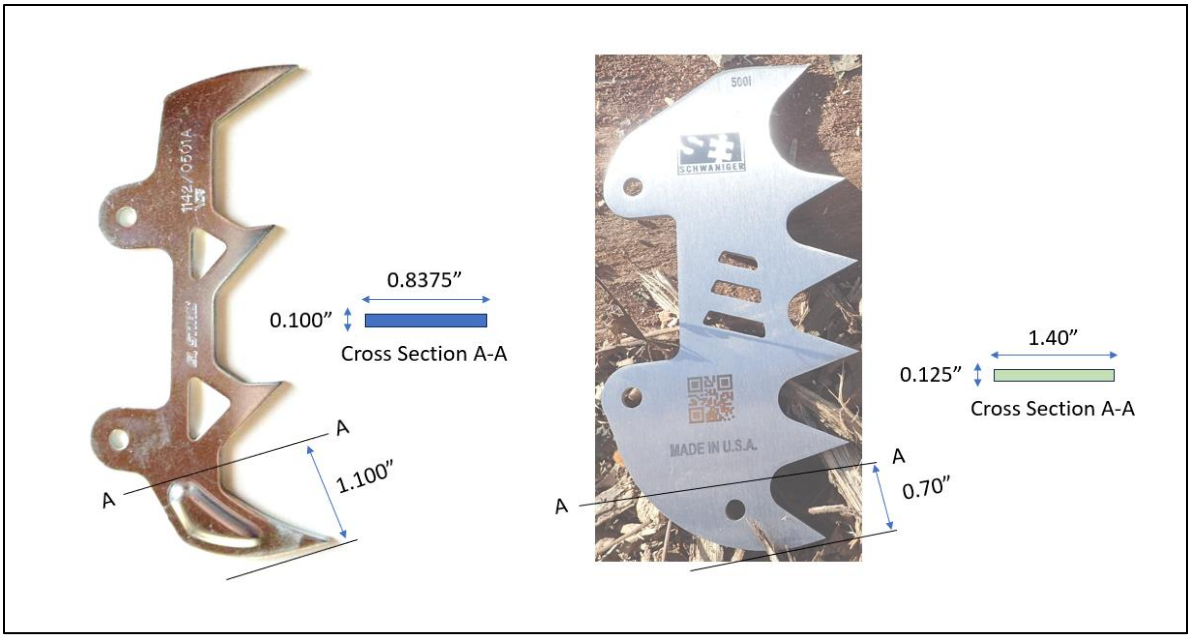

Figure 15 - Comparable Bending Sections A-A

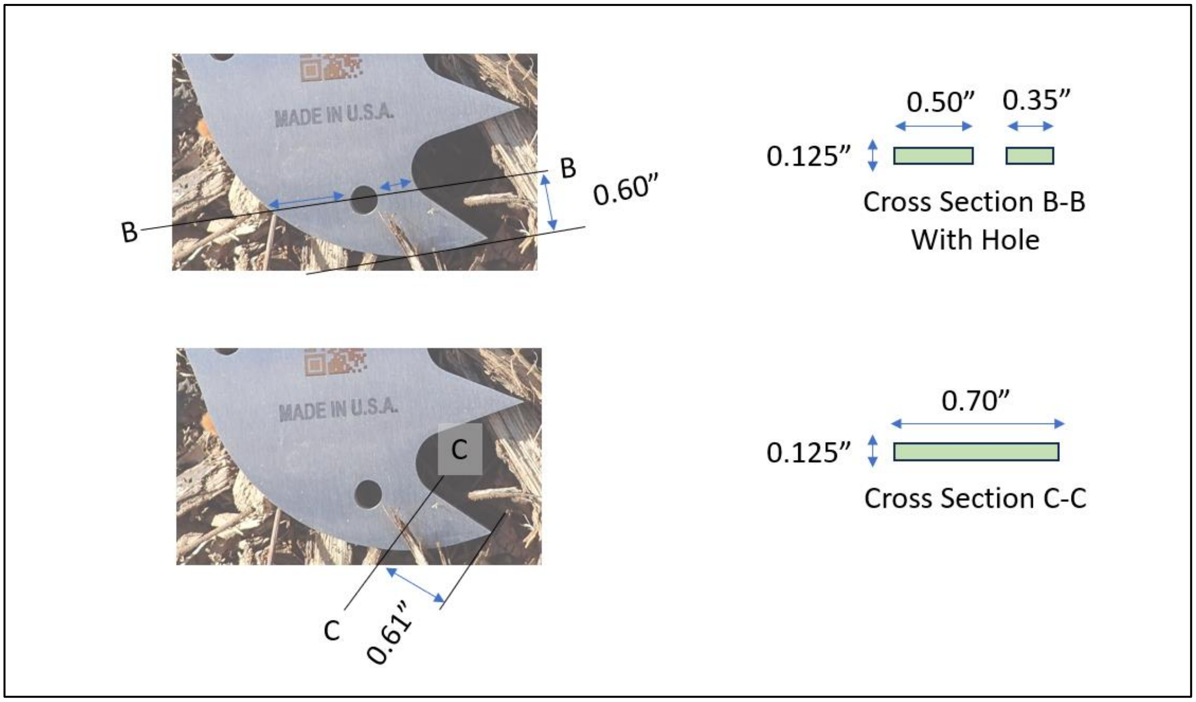

Figure 16 - Titanium Spike Bending Sections B-B & C-C

Section Properties:

Moments of inertia for each rectangular section are each calculated using

$$I = \frac{1}{12}bh^3$$

where I is moment of inertia about the section, b is width of the section, h is height of the section equating to material thickness.

Bending moment is calculated by

M = P(Arm)

where M is moment, P is applied sideward load, and Arm is moment arm, i.e. distance between applied load and the section being analyzed.

Stress is calculated via

$$\sigma = \frac{Mc}{I}$$

Where σ is bending stress in psi, M is bending moment in units of in-lbf, c is the distance from the neutral axis of each section to the outermost material fibers, and I is section moment of inertial. The c dimension for a rectangular section is simply half material thickness.

Table 3 - Section Properties Summary

Part	Section	Material	Width (in)	Thickness (in)	Moment Of Inertia (in^4)
			b	**h**	**I**
Stihl 1142 664 0501	A-A	Mild Stamped Steel	0.8375	0.100	0.00006979
Ti-DAWGS 500i	A-A	Grade 5 Titanium	1.4	0.125	0.00022786
Ti-DAWGS 500i	B-B	Grade 5 Titanium	0.85	0.125	0.00013835
Ti-DAWGS 500i	C-C	Grade 5 Titanium	0.7	0.125	0.00011393

Bending Stress and Results

Though felling spikes are intended to be loaded mostly in-plane, an applied sideward abuse load of 55 lbs for each case is assumed. The OEM felling spikes, made of 0.100 steel, exhibit permanent deformation with this load. The thicker titanium spikes with different shape and more robust design do not.

Bending stress under each scenario is compared to allowable stress in order to calculate a factor of safety using the relationship

$$MS = \frac{Allowable\ Stress}{Actual\ Stress} - 1$$

where MS is margin of safety, allowable stress is material yield stress, and actual stress is the calculated bending stress for each load condition and section.

Values for MS in the table below which are above zero indicate no material yield, i.e. no permanent deformation and values below zero result in bent parts, which is considered a failure affecting proper fit and function of chainsaw felling spikes.

Table 4 - Bending Stress Comparison for 55-lb Abuse Load

	Section		Bending Moment		Material Yield Strength	Margin of Safety			
Moment Arm (in)		**Force (lbf)**	**Moment (in-lbf)**	**Stress (psi)**	**Fty**	**MS**	**Result / Conclusion**		
1.1	A-A	55	60.5	43,343	42,000	-0.03	FAIL	BEND	Deform
0.7	A-A	55	38.5	10,560	100,000	8.47	Good	Stable	No Bending
0.6	B-B	55	33	14,908	100,000	5.71	Good	Stable	No Bending
0.61	C-C	55	33.55	18,405	100,000	4.43	Good	Stable	No Bending

As a further comparison, abuse loads are increased to near the yield point for titanium spikes. Comparison is shown in the table below.

Table 5 - Titanium Spike Bending Stress for Larger Abuse Loads

	Section		Bending Moment		Material Yield Strength	Margin of Safety			
Moment Arm (in)		**Force (lbf)**	**Moment (in-lbf)**	**Stress (psi)**	**Fty**	**MS**	**Result / Conclusion**		
0.7	A-A	285	199.5	54,720	100,000	0.83	Good	Stable	No Bending
0.6	B-B	285	171	77,252	100,000	0.29	Good	Stable	No Bending
0.61	C-C	285	173.85	95,369	100,000	0.04	Good	Stable	No Bending

Titanium spikes show a comfortably positive safety margin for a sidward abuse load of 285 lbs. OEM spikes bend at 55 lbs in this comparison. Titanium spikes of the design shown above can therefore handle 285 lbs vs. 55 for OEM, which is over 5x the abuse load.

Note:

The OEM larger spikes, shown in Figure 2, are not evaluated here. However, the material used for them appears to be the same, spike thickness is the same (0.100”), and they are larger with correspondingly larger bending moment under the sideward-directed abuse load. These spikes are not anticipated to fare much better in similar analysis.

Chain Catcher:

Another factor to consider is the addition of the 1122 650 7702 chain catcher to the titanium spikes as shown below, which is not an option for the smaller style OEM spikes evaluated in this document. This chain catcher facilitates at least partial sharing of abuse loads between the outer spike and the inner spike, thus forming a tandem pair working more in unison, especially for forces tending to squeeze the spikes toward each other. This strengthens the spikes beyond any conservative calculations shown above.

Figure 17 - Optional OEM Chain Catcher on Titanium Spikes

Conclusion

Bumper Spikes / Felling Dogs / Felling Spikes are desired by many tree fallers and professional loggers and tree service personnel because they enable the saw to perform certain tasks which are not possible without them.

Titanium felling spikes made of titanium, which are of a different shape and thickness than OEM, offer increased resistance to applied forces.

In particular, the titanium spikes made for the smaller clutch cover on the 500i offer the following advantages over their OEM counterparts:

1) Larger, more plentiful, and sharper spikes for felling and heavy bucking
2) Option of OEM cylindrical chain catcher for safer saw operation and better spike support
3) Higher overall strength due to more efficient shape and thicker, stronger material
4) Better corrosion resistance and better aesthetics than OEM