The Miracle of Fire by Friction
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Introduction

Starting a tire by rubbing two sticks together. Why do I always get a thrill out of doing it? Is it because there are probably less than 500 people in the United States who can consistently start a fire with a hand drill? Is it the entertainer in me? I don't know. I assure you that the thrill is not diminished by knowing more about the scientific events that go on during the process.

The objective of this article is to provide some scientific insight into the events which happen when two sticks are rubbed together to start a fire. In particular, why is it that some woods don't work at all, some work with great effort and others with relative ease. The principals discussed apply equally well to the fire saw, fire plow, hand spun drill or bow drill. Will it help you start a friction fire more easily or quickly? Probably not. Will it give you a deeper appreciation of the process? I hope so.

Basic Principals

You have to get the char, powder that is rubbed off the wood, heated up to about 800 degrees Fahrenheit before it will start glowing (ignite). I measured this by sprinkling char generated with a bow drill on a soldering iron heated up to a known temperature. Below 800 degrees the wood dust would give off a little smoke but that's all. Above 800 it would smoke and then start to glow. Anything that prevents the char from reaching 800 degrees will interfere with fire making.

Composition and Structure

By this I mean what kind of molecules is the material composed of and how are the molecules arranged? If there is any volatile resin or tarry substance in the wood then as the friction heats the wood the tarry stuff will take heat away from the char (heat of evaporation) or will condense on the char and form it into a coarse gritty substance, preventing ignition. If the correct molecules are present and all the wrong molecules are absent there is still a problem if the molecules are not arranged properly. Imagine your best hearth board and hand spun spindle, which will twirl up an ember with very little effort. The wood will be very light, a very poor thermal conductor (a good insulator). Now put your hearth board and spindle in a vice and compress the wood to 1/2 its original thickness. It will be twice as dense and its thermal conductivity will be doubled. You can still twirl up an ember but you will have to work twice as hard because you have altered the structure of the wood. You have made it a poorer insulator and you have doubled the amount of muscle power needed to reach ignition. For a person with limited muscle power attempting to start a tire by friction the use of low-density wood is critical.

The simplest test for whether a particular piece of wood will twirl up an ember is the most obvious: try it and see if it works. A quicker test is to examine the char that is ground off as you twirl the spindle on the hearth board. The rule of thumb, literally, is to rub the char between thumb and forefinger. If it is coarse and gritty then reject that particular piece of wood. If it is very fine, like face powder, then you have a good chance of twirling up a fire. Both Kochansky and Graves mention this. What is the difference between these two classes of wood? Those that work and those that don't. We know that in the category of "good" woods there are softwoods, such as yucca, which can be easily dented with the thumbnail and hard woods such as sagebrush, which are much more resistant to the thumbnail test. Could it be that the "good" woods ignite at a lower temperature than the "bad" woods? That should be easy to measure. The straightforward way would be to measure the temperature of each tiny little particle of char as it is ground off the spindle or hearth board. Trouble is that it is very hard to measure the temperature of something that tiny without disturbing what is going on. The next best way is to measure the ignition temperature indirectly. Sprinkle some char on a piece of metal which has been heated to a known temperature. See what temperature the metal has to be heated to in order to ignite the char. As a practical manner I used a thermostatically controlled soldering iron as a source of known temperature. Tips with two different temperatures, 700 deg.-F and 800 deg.-F were available. I had observed previously that the char ground into the notch in a "good" hearthboard would start glowing (ignite) if a pinch of it was placed on the 800 degree soldering iron tip but would not ignite if placed on the 700 degree tip. The conclusion from this was that if friction heats the char above 800 degrees it will ignite.

What about "bad" woods? I used a piece of local willow sapwood, a material on which I have wasted countless hours in the past trying to light a friction fire. Never any luck. Always produces a coarse gritty char. This time I did a different experiment. I charred some of the willow with a match and then ground it off with a file. It was now very fine, much finer than the results of a bow drill. This very fine willow char would ignite almost instantaneously at 700 degrees. Conclusion: the more finely the char is divided the lower the ignition temperature. This hypothesis was tested further by grinding off some un-charred mule fat wood with a fairly fine file. This material was slightly gritty feeling compared with the char that falls into the notch of a mule fat hearth board. The coarser mule fat char failed to ignite at 800 degrees. I did the same thing with char cloth, the favored tinder for flint and steel. Char cloth failed to ignite, even at 800 degrees.

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Conclusions

The miracle of fire by friction is that you don't have to heat the char up to the temperature of a glowing ember to make it ignite. You only have to raise its temperature up to the point where it takes off of its own accord. When powdered charred wood is heated up to some critical temperature it begins to spontaneously oxidize. When it starts oxidizing its temperature rises, causing it to oxidize even faster. Eventually it reaches an equilibrium temperature limited by how much air is available and starts to glow, ignition. The critical temperature where this process begins depends on how finely the char is pulverized.

Fire by friction works only because these two events, pulverizing and heating, happen simultaneously. Woods that don't work disintegrate before they reach this critical condition.

Fire by Friction - The Spiritual Aspects

What is a cynical, agnostic engineer doing talking about the "spiritual" nature of something which can be fully explained by the laws of physics and chemistry? All I know is that there are some things that make me feel good and starting a fire the way my ancestors did 10,000 years ago is one of them. What makes me feel even better is getting a group of people to contribute towards the starting of a fire. I can think of no better way to bond a group of people. We all take turns at twirling the spindle, each according to his or her own ability, we all gently blow on the ember to bring out the flame and the smoke carries our thoughts and our hopes skyward. On the evaluation of a weekend course I gave a couple of years ago one of the students said, "Starting a fire is a sacrament." I guess it is.

Things that can cause problems:

a. If you don't have enough muscle power then you won't be able to raise the temperature high enough. Remedy: teamwork. Have someone else help you. Even if the helper can only get the wood temperature elevated to 300 degrees then it will make the job easier. Remember that a bow drill is the easiest in that it uses your muscle power most effectively.

b. If the structure of the wood is such that it disintegrates before it reaches 800 degrees then it is a wood that should not be used. I strongly believe that some softwoods such as willow and aspen don't work because they fall apart before they reach the critical temperature.

c. Volatile substances such as water or resin in the wood. Evaporative cooling will prevent the char from reaching the critical temperature.
