Just Fracture Matches_2018IPTES_032

Intro [00:00:05] Now this is recording. RTI International Center for Forensic Science Presents Just Science.

Intro [00:00:20] Welcome to Just Science, a podcast for forensic science professionals and anyone who's interested in learning more about how real crime laboratories work. In this season, we will cover content given at the NIJ Forensic Technology Center of Excellence's Impression Pattern and Trace Evidence Symposium. If you missed the symposium, you can view the archives at forensicceo.org. In episode two of the IPTES season Just Science interviews Dr. Ashraf Bastawros from Iowa State University. Dr. Bastawros discusses how fracture mechanics principles can be used with statistical learning tools to give quantitative results. Explore the mind of an engineer and how leveraging other disciplines can aid forensic science. This season is funded by the National Institute of Justice's Forensic Technology Center of Excellence. Here's your host, Dr. John Morgan.

Dr. John Morgan [00:01:14] And welcome to Just Science, the podcast for Forensic Science Professionals. I'm John Morgan, your host. We're here at the Impression Pattern Trace Evidence Symposium in Arlington, Virginia, and today's podcast. We're talking to Ashraf Bastawros. He is the T. A. Wilson Professor of engineering in the aerospace engineering department at Iowa State University, also is, of course, associated with the DOE's Ames Laboratory as well. He's an associate there. His research, which is near and dear to my heart. As regular listeners know, my background is in materials science, although not metallurgy. My work was in optoelectronic semiconductors, but this is cool stuff and his strength is in linking micro structures and continuum theory through fundamental and applied experimental research. And he's got a paper that he's giving here at IPTES on fracture mechanics based quantitative matching of forensic evidence fragments. And in particular you're looking at metals, is that right? Brittle metals.

Dr. Ashraf Bastawros [00:02:10] Yes, brittle metals.

Dr. John Morgan [00:02:11] And so we're going to be talking a lot today about looking at the surface topography of these fractures and how some fundamental examination of the physics of those fractures, as well as doing some quantitative analysis, can go together to try to help forensic scientists do their work. You are also an example of a good researcher practitioner partnership. You actually work pretty closely, I know, with at least John Vanderkolk, right?

Dr. Ashraf Bastawros [00:02:36] Oh yeah. He's the one who introduced me to the whole topic.

Dr. John Morgan [00:02:39] Okay, excellent. Well, we just did a podcast, so we're very, very pleased to have you. Welcome.

Dr. Ashraf Bastawros [00:02:45] Thank you. Appreciate it.

Dr. John Morgan [00:02:46] How did you meet John? How did that work?

Dr. Ashraf Bastawros [00:02:48] That was quite interesting. A long time ago at Iowa State, we have a Midwest forensics center, and through the center many forensic practitioners would come for workshop, for presentation. And so for us, where I got to know him close to ten years ago. Back then the first things I saw, he was like putting pieces together for comparison. So when I looked at that and one of the issues hit my head, well, we always look at fracture as a property of a material. We never cared like after that fracture, do I put pieces together or not, but I felt there is a lot we can contribute to the field from a material science and fracture mechanics point of view that may meet our help in the comparative process.

Dr. John Morgan [00:03:31] Now, John likes to talk about natural and natural processes and the variation. You know, his view is that unnatural processes can be repeated and natural processes cannot be repeated. Now there's a lot of depth behind that. Is that an etiology that he's discussed with you and how do you feel about that?

Dr. Ashraf Bastawros [00:03:50] Yes, like what he describe it as a natural or unnatural. We divided like this how he divided, but we divided in our language to be something akin to the material or microstructure and something that is uncontrollable, which is the applied loading that induce the fracture so is the are like very similar to each other but just different semantics.

Dr. John Morgan [00:04:10] I talked to him about a particular example and that is my windshield. So as we speak a few weeks ago, I don't know what hit my windshield but something hit my windshield and it made a little ding. You know, we've all seen the little spider web kind of pattern out of that. And then over the weekend, there was a propagation that occurred right.

Dr. Ashraf Bastawros [00:04:28] (Indiscernible) things came powder.

Dr. John Morgan [00:04:30] Well, now it's still intact for the time being because I had I had to get right here to the conference, but it didn't propagate across the wind shear.

Dr. Ashraf Bastawros [00:04:38] And it propagate in a very funny way. And you wonder why is the crack sterling?

Dr. John Morgan [00:04:42] Interestingly, there was a curvature to the, to the line. It was, you know, it was kind of like a, an approximation off of a straight line if you were drunk, right? So my argument to him is that propagation line is not unique. Well, first of all, glasses and crystal and, right?

Dr. Ashraf Bastawros [00:04:57] Right.

Dr. John Morgan [00:04:58] And those lines are determined in large measure by some basic physics of how glass fractures. And therefore, I'm not sure if you have you pull apart those two pieces, how easy it would be to match them up again against a large population of windshield pairs.

Dr. Ashraf Bastawros [00:05:18] Well, let me separate a little bit here about windshield, because windshield is a very special glass, which is triplex. You have an inner layer, you have a polymer layer in the middle and you have an outer layer. So when you get the storms that hit your glass and you get fracture, the outer layer start to break, but the inner layer still intact. That's why you still have your whole windshield as one piece.

Dr. John Morgan [00:05:39] Okay.

[00:05:40] So that is one type. The other type is a single layer, but pre stressed. And when it get to head, the whole glass sheet would become a partition.

Dr. John Morgan [00:05:49] Okay.

Dr. Ashraf Bastawros [00:05:49] Okay.

Dr. John Morgan [00:05:50] And we had that happen, too.

Dr. Ashraf Bastawros [00:05:51] Yes. And that is primary like your front shield will have the polymer layer, the side windows will be unreinforced. So as the if you get the hit from side window, it will become a powder.

Dr. John Morgan [00:06:02] My car actually a few months ago got hit by a deer and did exactly that. So we had I feels like a million and might have been...

Dr. Ashraf Bastawros [00:06:11] Yes.

Dr. John Morgan [00:06:12] pieces of glass on the back of the car. Backseat of the car.

Dr. Ashraf Bastawros [00:06:14] That was the. But where does it come from? The windshield or from the side door.

Dr. John Morgan [00:06:18] It came from the side. It was a side hit, right? Yeah.

Dr. Ashraf Bastawros [00:06:21] And the whole idea here in designing of those glasses that you never have a big piece that if fractured, it can cut the passenger, but if they are powder, you'll just like, you'll get some scratches and nothing will happen. The driver is there. You have what we call residual stresses built into the glass. So once you get a crack, if it doesn't have the reinforcement, you have all the defect in the glass will nucleate cracks. And that's how you get this pulverization. Okay. So we have many, many nucleation sites that will generate cracks. And it is more or less random. Not only is that this powder part that you got, you will not be able to put it back together. Yes. This is like a million piece puzzle. And you try to put it is quite hard. You can like if you stayed months to do it, you can, but you will get a lot of similarity from if you break it in different sheets, it would be impossible to separate them. As the front windshield, when it is a 3X one it has a polymer layer. So if you get a crack, let the crack run on the outer layer. The inner layer will stay intact and the direction of the crack is almost will be parallel to the lowest curvature of your panel. Okay. So that's why it went like horizontal in the middle part. And once the go to the curves, it will start to go in a different trajectory because this curvature have again residual stresses and it will drive the crack in what we call is the lowest energy direction. So in general, the direction of the crack is determined by how is the overall configuration. But the local roughness of those cracks will be different. Okay, so if you get ten panels and you hit it almost as the same position, you will get the crack propagate on a macroscale it looks the same. On a micro scale or at a different viewing, a field of view you'll find they are very different. Okay. And that is how the uniqueness of this process is like stemming from that.

Dr. John Morgan [00:08:17] So in your research work that at least what you're presenting here, right, at the IPTES is on Microcrystalline metal.

Dr. Ashraf Bastawros [00:08:23] Yes. Micro or metal like crystal and metals or could be amorphous metals.

Dr. John Morgan [00:08:28] But those are generally pliable, more pliable than a microcrystalline or crystal and metal.

Dr. Ashraf Bastawros [00:08:32] Yes, but here is a trick. When we sort of sample materials that we work with, most articles encountered in forensic field will be hardened to steel because they will be pry tools which is hardened steel, or it will be stainless steel like a cutlery, knives or edges or the like. And all of those have like, you know, hardened meaning you can have a little bit of plastic deformation and then it will fracture. And those are very different than like ductile material where you will get a very large plastic deformation. And when you break it, you get the intricate local deformation from the two pieces.

Dr. John Morgan [00:09:12] In general, a harder material is going to be more brittle.

Dr. Ashraf Bastawros [00:09:14] Yes. And that is what is encountered primarily in forensic field. Now, what is the difference between a ductile fracture and a brittle fracture? A brittle fracture in metals? When it fracture, you will get two pieces that you put them together. They will fit quite nicely. So it is like a jigsaw puzzle that you fill them. If it is ductile locally, the plastic deformation, you will get a lot of dimpling and a metal extrusion that you try to put them together. The look matching but locally they will not.

Dr. John Morgan [00:09:44] Right.

Dr. Ashraf Bastawros [00:09:44] Because of the local ductal deformation.

Dr. John Morgan [00:09:48] So in general, when you have a brittle deformation, you're more likely to get a break line that you can, we can call it individualization, but it can certainly do a comparison that's reasonable.

Dr. Ashraf Bastawros [00:09:57] Actually you can do it in both ways, but you just you have to take to account this local deformation. But the classic ones that is encountered mostly in forensic field will be hard metals or hardened materials.

Dr. John Morgan [00:10:10] Sure.

Dr. Ashraf Bastawros [00:10:10] Like is there heat treated or alloyed? Because that is the nature of most of our like cutter or pry tools.

Dr. John Morgan [00:10:17] Back when I used to do real science, I didn't avoid metals altogether. So we actually did some work in amorphous magnetic materials.

Dr. Ashraf Bastawros [00:10:23] Yes.

[00:10:24] Which as you know probably, are very, very popular in DC Electric Motors and Transformers these days. Very important materials. And we did a we did a solid state physics laboratory course in those. So we would take, you know, some alloy of iron boride, you know, iron aluminum boride or whatever, which are relatively easy to create in an amorphous, non crystalline format. And they're nice and ductile and they also have very good magnetic properties in the sense they are relatively lossless, right? And they're very particular transport properties as well, especially as you go down in temperature, they look like nice classic metals. And then what we would have them do is we would have them crystallize them and then the same compositionally, of course, but their microstructure is changed, they become brittle and the students would often have an easy time working with the native material, the amorphous material. But when they got brittle, they would often break. You had to be very gentle.

Dr. Ashraf Bastawros [00:11:21] Touch it to the floor. Yeah.

Dr. John Morgan [00:11:23] Exactly. And of course their properties went to heck as magnetic materials became very, very lossy magnetic materials. So it was a fun, fun demonstration of what you're talking about in that regard.

Dr. Ashraf Bastawros [00:11:32] And also was the other part for the symmetry, like even steel, if it is heat treated, if you load it slowly, you can get it to fracture slightly in a ductile way. If you load it in a fast way, it will be become more brittle. So that is the time dependent response of metallic materials. And most for a relevant to forensic field will be like the fast loading. Because when you are breaking up pry tools just they are loading and suddenly it will snap.

Dr. John Morgan [00:12:00] Okay.

Dr. Ashraf Bastawros [00:12:01] Okay. Or in an accident, a high impact or so. So that will be like akin more to the high (indiscernible) loading. Okay. So it will be more brittle than ductile but is still the framework we developed would apply to (indiscernible). Just you have to account to that deformation.

Dr. John Morgan [00:12:18] And of course in the laboratory it's very easy to look at all that you I'm sure you have a tensile testers. That's very easy to do that kind of work.

Dr. Ashraf Bastawros [00:12:25] When we're doing it for forensic, we did it in two steps.

Dr. John Morgan [00:12:29] Okay.

Dr. Ashraf Bastawros [00:12:30] So the first one we did a controlled fracture where we brought either knives or stainless steel bars and we load it in what we call slip point bend or just like a bend configuration in a very controlled way. And we were afraid, actually, that since this process, very controlled, will not be able to distinguish between the fracture surfaces. And amazingly, if you put like we did it in groups of ten so we put the ten sample together, the first visual that the fracture trajectory or cracked trajectory they look the same. But when you try to look at the topology of that fracture surface on the fracture pieces, they are very different because they are controlled from multiple parameters. And those multiple parameters really showed that the process is unique to every event.

Dr. John Morgan [00:13:16] I see. Now that you're going to have different alloys, are going to have different macro characteristics or class characteristics in their fracture mechanics, right? Tell us about your particular research project. When you say theory to start with, what were you trying to do?

Dr. Ashraf Bastawros [00:13:28] Since you say the class characteristics? So for example, let's pick alloy that is used for my observatory in particular, like the 440 steel. Okay. If you take any manufacturers, you'll have their trade secrets and the alloying that they add and the heat treatments they do for the alloy. So if I take, like, either a set of sample of knives from the same manufacturer, either manufacture consecutively or randomly, you'll find a particular class characteristic in those which will be at the range of the grain size and grain distribution, where they are all done by the same process you get the statistical distribution of the grain to be the same. If I get Knife A, Knife B, Knife C, I check it they all look the same. Then if I go down to the micro mechanism of failure, like if I say grain is about the range of the alloy anywhere from five micron to 50 micron and because it varies, how is it processed? So you'll get that distribution. But then if I go further down the scale, how is this grain a (indiscernible) from each other or break? So that is the local material resistance to fracture. And this is akin to the material that it will form dimples. The dimples will look the same. So if I go down as a scale, all fracture looks the same and they will be indistinguishable. So that is what is dictated by the material.

Dr. John Morgan [00:14:51] That's interesting. Yeah. So it must break at the boundaries between. Right. Small crystals or grains and material.

Dr. Ashraf Bastawros [00:14:58] Right. And when they break the are like here is a particular mechanism that will interact between a local deposit as a grain boundary and you will see some little dimples or cleavage fracture. And if I get you like ten fracture surfaces at that scale, which is will be in the range of ten micron to a lower level that usually see it by SCM. You will not be able to distinguish between them.

Dr. John Morgan [00:15:22] So whereas for 440 stainless what you used for all of your work?

Dr. Ashraf Bastawros [00:15:26] I use a couple of alloys, but for 440 was one of the common ones.

Dr. John Morgan [00:15:29] Okay, so the knife manufacturers actually are that much different. So they'll start with the same composition alloy, but they will actually do such different heat treatments that you're actually seeing differences in the grain sizes.

Dr. Ashraf Bastawros [00:15:40] Yes, our grain size. Well, this is a very interesting issue. Get any knife? Okay. That has from the spine to the edge with a little curvature. They do that actually, by rolling. And because of that rolling, you will find that at the edge. The cutting edge grains are in the order of 10 to 20 micron. At the spine, which is a thicker part of the blade, the grains could be from 80 to 100 micron in the same blade.

Dr. John Morgan [00:16:07] I see.

Dr. Ashraf Bastawros [00:16:08] So knives is a very unique beast because of the how it is processed. You get the variability of the grain microstructure within the knife.

Dr. John Morgan [00:16:16] I've never really thought about it from the perspective of sharpening, for example. I mean, so a, I assume a more finely grained material would be easier and more it would be more effective in terms of what the sharpening will do for you. But it also is going to be much more brittle as well.

Dr. Ashraf Bastawros [00:16:34] No, actually, this is the conundrum of all cutting tools or chisels. Any or any of this forming tools is that you need it to be as brittle and as hard as it could be on the surface. And you need it to be in the core of it ductile. So any of those cutting tools you have to get this gradient in the microstructure.

Dr. John Morgan [00:16:54] So you so I guess there's a lot of quenching involved. Yeah.

Dr. Ashraf Bastawros [00:16:57] Exactly. That is the classical quenching or heat treatments that like if all these steel smith guys that used to do chisels. You heat it, then you quench it quickly and you pull it out. And this is like you'd get hardening for the surface. You get fine grain, you pull it out, you get the core heat to do a retreatment. Then you leave it a little bit in the air to it to stabilize. Then you quench it in oil. So you do it on water, then you do it in oil.

Dr. John Morgan [00:17:25] Okay.

Dr. Ashraf Bastawros [00:17:25] So there is like even those like steel smiths that's used to do it by hand. (Indiscernible) is the trick. Same things for cutting tools. You need the edge to be refined grains harder. But the core of the blade to be more bigger grains to be ductile. So when you are hammering with that, you don't snap it every time you are trying to cut something hard.

Dr. John Morgan [00:17:44] Sure. And then over time, after you have ground down that edge, pretty much you're down to the ductile material and it's worthless.

Dr. Ashraf Bastawros [00:17:49] Then it is worthless. Actually is not worthless. What would happen is that every time you try to use it, it will dull very quickly. So this is a little bit of art in the whole process. So back again to the problem of fracture.

Dr. John Morgan [00:18:03] Yes.

Dr. Ashraf Bastawros [00:18:03] The fracturing. An article found in a forensic study. You have features on the fracture surface that is akin to the material and to the microstructure, that is, for example, the grain distribution. And those are one that is akin to the processing that happened to the blade, which coming from the heat treatment. So for that will control the micro mechanism of failure, which will be like, for example, in a simple way, a ductile versus brittle failure. And from that perspective, you bring a hundred knives, you will all look alike in that range. And that range now is a grain size, let's say tens of micron. And the submarine size, which is the micro mechanism or Micron Nano mechanism failure, which go from sub micron all the way to the nanometer scale. You look on fracture surfaces, they all look alike. So what is the distinction here? The distinction is coming from, let me bring it from fracture mechanics, that when you apply your external loading on a sample, the way you apply it is unique not to samples when you are trying to load it will be the same. Even if it is loaded in a systematic way, like in a pencil test. How so? Because when I am loading my sample in a fracture or in pencil frame or in a bending frame, the cracking will start from the local in homogeneity. Right. Okay. And this is one that is will be statistically different from one sample to another. Then you will say, okay, why if I put a glass piece and I break it, I get a powder? And when I put a metal piece, I break it, I get one crack, typically 1 or 2? This goes to a very different trick that in glass you have too many defect. Okay. And when I apply, a load.

Dr. John Morgan [00:19:49] Glass is basically a whole bunch of defects.

Dr. Ashraf Bastawros [00:19:51] Right? And when I apply a load on that, all this defects will propagate and the inertia will take a big effect there that you will get percolation of too many cracks propagate in parallel. So that's why you get a powder. But when I have a metal, I have many stochastic defect. I get what will call it a stress riser or high loading point. But only while I have high loading point. The weakest link will run first. And once it run, since it is slightly compliant, it can unload the rest and get one crack run.

Dr. John Morgan [00:20:25] Sure. So if you have a point that is a millimeter across and you have five micron grain sizes, there's thousands of points that could be subject to that, which could be your weak point and the...

Dr. Ashraf Bastawros [00:20:38] Then when that crack is running, it will, in its trajectory, select the weak point all the time. So that is how uniqueness is coming. Okay. Is that you have bunch of stochastic distribution of defect and a crack is running, picking those weak point. That is how you get, like, two cracks will never be alike. Or that is how it posts or is this a premises of uniqueness from one surface to another?

Dr. John Morgan [00:21:03] So theoretically, if you have a broken knife, you have one half of the knife and you're trying to match up the other one. There should be a unique way in which John told me that you really despise this idea that he's going to, like, crunch them together because that's semi destructive. Right? Hypothetically, let's just say if you did that, you should be it should be unique in that regard.

Dr. Ashraf Bastawros [00:21:24] That is correct. And what we should like, let me be careful of what we are doing versus a forensic practitioner what he or she are doing. In forensic science, how do they do the matching? First, they try to do visual. They put the two pieces. So if they fit, that is like puzzle. They start to think, okay, is there is probability of a match? So these first things is a visual inspection and sees that okay, is a dimension fit and so forth. And by the way, no matter how much we put computerized level, we need that initial screen. Then they do the second part by doing comparative microscopy, as he puts it, two halves under a microscope as they look for common features between them. So to this extent is excellent. I mean, nothing can refute that and that is how it is done. However, after you do that, we always what is the point of attack that this is subjective and you have no statistical basis of the process, right. So that is the true culprit that is really weak in the techniques that you do. Yes. I mean, features are common, but you always ask, how unique are those features? If I put hundred sample, am I ever going to get that or not? You cannot answer that by just qualitative comparisons. So the power of what we try to do is we try to see, okay, what is the feature we can measure? We can numerically quantify as a number and we can use it in a statistical model. So when we say it is a match, here's a probability of a match. And when it is what you did visually, no, it is fundamentally acceptable with quantified error. So that is what we really try to do is support that what forensic scientists do visually from the basics of fracture mechanics and from material science. And add to that a big part of statistical analysis we did to really do this quantification and prove or find quantified probability for the process.

Dr. John Morgan [00:23:18] Now, when you did your imaging of the surfaces, you used optical interferometry. The ZYGO instrument.

Dr. Ashraf Bastawros [00:23:26] Actually the ZYGO is it seems, it is quite funny. We use ZYGO for about like 12, 15 years. It is like technologies that stemmed maybe at early or late 90s, early 2000s and start to be common in material science as a topology or topographic tools that bridge in the old technology of stylus. And with a very high resolution that you go to the range of the submicron level very easily from optical measurement.

Dr. John Morgan [00:24:00] Now, just so the folks at home know, if you want to learn more about optical topography, we have actually, our center has not only done a landscape report on different systems for use in firearms examination, but I just did a webinar here recently.

Dr. Ashraf Bastawros [00:24:15] I just heard it.

Dr. John Morgan [00:24:15] Did you listen?

Dr. Ashraf Bastawros [00:24:16] Yes. It was excellent.

Dr. John Morgan [00:24:18] Thank you. And so it's actually, I think something that's going to become more common in the crime laboratory.

Dr. Ashraf Bastawros [00:24:23] Yes.

Dr. John Morgan [00:24:23] I don't know if anybody has put an interferometry based system into a crime laboratory.

Dr. Ashraf Bastawros [00:24:28] I think I saw one couple of years ago, but I got a lot of comments from them that they have a very hard time of how to use it in forensic. Yeah, and it is unless you really know what you are doing, you can get a very deceiving result out of it. And actually John Vanderkolk helped me quite a bit because I found that you have to be very restrictive of how you handle the sample and how we align it and so forth. And I was telling him like we found that really for our technique to work I need to put all of those constraints. So he bumped me and he says, Well, I'll share that's what we do in comparative microscope is that if you don't align your sample well, and if you don't really get the lightning on the two halves to be exact, you will not get the same features in your field of view. So it is a common practice that you do all of this initial alignment. And obviously two halves when you're (indiscernible) if you don't do that, you will get a very deceiving result. So it is the same techniques you use. You have to import it to this more sophisticated tool to try to apply.

Dr. John Morgan [00:25:28] So in terms of the characterization, the algorithm you use to develop a statistical representation of a surface. Is that something that you all developed yourself or?

Dr. Ashraf Bastawros [00:25:37] Yes. So let me divide it to three pieces.

Dr. John Morgan [00:25:40] Okay.

Dr. Ashraf Bastawros [00:25:41] We have first is the microscope that you get the initial image and the initial image is nothing, but think of it as the height distribution over a grid of the surface. Now, that initial image, not every image will work for you because even that microscope is powerful. It has its own limitation. For example, if you have a very deep crevice, you will not be able to emit correctly because you get a light shadowing effect. So you get a little bit of not uncertainty, but there is an error in how you get the image. You have to know it and you have to be clear about those. So we have first you get your image, then we do a cleaning phase of all this, either missing data or what we think it is out of bound data just eliminated. Now, are we cooking or doctoring in? No. This is a standard image processing techniques for all handling of images.

Dr. John Morgan [00:26:33] Now, you know, there are some folks and I.

Dr. Ashraf Bastawros [00:26:34] Yes.

Dr. John Morgan [00:26:35] Who are very critical of any kind of looking at anything other than raw data.

Dr. Ashraf Bastawros [00:26:40] And this is where we have to really work hard. And I really comment this podcast that (indiscernible), the community, especially lawyers and defense lawyers. I'll tell you, the very first numerically altered image was done when a fingerprint, I think in early 2000s was lifted from a pillow, pillowcase. And just when you look at zero image, you cannot see anything. You see the picture of the pillow. But once it is mathematically a well known technique with the theoretical foundations that if I subtract the picture of the pillow from that image, immediately you see the fingerprint? So for that case, I can't remember the exact number of the case, but for that case, lawyers were saying, you doctored in the process. And actually no, we have the information. We separate the background from the fingerprint. And once you did that, you see the fingerprint. Very clear. So this is where I think for a non forensic person like myself, I can provide the background for any of those techniques. So when we get a heat from a non-expert about any of those techniques, says, nope, this is how the science work and here is a fundamental basis of it and how we can use it in a very methodical way.

Dr. John Morgan [00:27:54] Sure. And I think saying it in a methodical way is the critical issue here. Yes. That is that you're not just playing around with me. You're using a very particular way of.

Dr. Ashraf Bastawros [00:28:05] This is very well established field for 56 years now of digital image processing. Yeah. And there is all the artifact. I was telling you they are well-characterized in the field we call a salt and pepper noise where you get like a high response from one local pixel. But the overall pattern, it is a seam. I'm not doctoring and any details, just I am removing what we call a high frequency noise or a noise that is just imposed from the measurement.

Dr. John Morgan [00:28:32] Right.

Dr. Ashraf Bastawros [00:28:32] And they have no effect on the base image that you get. And by the way, any camera or like even your cell phone, when you take a picture, you didn't know that not every pixel in your phone is working, right? I'm not sure if you know that or not. In manufacturing, of those cell phones array, you get a defective pixel. So when you get the defective pixel was it is something called the lookup table is that actually it can do multiple things easier to do a correction factor for the bad pixel response or it can take the average of surrounding and substitute to that. And that is how when you get your picture, you get it edited or very nice presented. Right? And this is an all digital translation of from between a physical image and a digital image. And it is a standard. You have like thousands and thousands of papers defending all of those techniques.

Dr. John Morgan [00:29:23] Well, I mean, there's something fundamental about it. You know, measurement by itself is a representation.

Dr. Ashraf Bastawros [00:29:28] Is a representation with an error. And with the noise and all of that, and let's just clear the field, put the fact and here is it. It is the same way how we process a DNA. So it is the same way. This is like a new technique for us. And we have to put the fundamentals of how we process those images. So that was the first part. Getting the image in the right way. Then the second part is the start of what we call analysis. And analysis is we take that image would break it to the size scale or what we call it, frequency component or (indiscernible) piece. And in a different way think of it if you want to look at an image or if you look like, for example, the room we are sitting in, if I want to tell you, build this room. So if to me, okay, give me the dimension and I'll start to build it. Or in a different way. I can give you a bill of materials. Bill of materials, meaning, okay, I need how many bricks I need, how many windows, The size of bricks, the size of windows. So the bill of material, when I describe it like that, that's what we call it, the frequency component or the characteristics of wavelengths on the image. Sure. Okay. When I give you the dimensions, that is the what we call the physical space. So first you take the image in the physical space, then we dissect it to its wavelengths or frequency component. And this is what we do in the mathematical free transform. Again, another standard way.

Dr. John Morgan [00:30:49] At this point. Also you need to have an understanding of what your hypothesis is going to be about where the characteristic.

Dr. Ashraf Bastawros [00:30:54] Exactly.

Dr. John Morgan [00:30:55] So are you going so far as saying, well, some of this, you know, at the five micron level, as we were talking about before, is not relevant to the individualization of the crack?

Dr. Ashraf Bastawros [00:31:05] Exactly. So let me take you backward, which is which scale I should image? Yeah. Okay. How big and what does the resolution of taking the scale for the analysis for now. Yeah. So this one will come from two part. First, I have to understand the material and the material. The parameter I want from it is the grain size. How big is the grain? So you give me a material. One has a five micron grain and material two has 100 micron grain. So which field of view I should look at? That was the first question we have. So this answer comes from two steps. The first one is the details of the fracture from fracture mechanics tells me that you have hit every crack, what we call a process zone, the process zone, size of interest. We prove it to be two grain size. So the first skill here should be two grain size in a size two grain size will be ten is 100 micron to grain, size would be 200 micron.

Dr. John Morgan [00:32:04] Does the breadth of the distribution affect that or usually or is it are they usually more controlled than that? Some materials you might have a range of like 3 to 7 microns some. Yeah.

Dr. Ashraf Bastawros [00:32:14] Right. So the like whenever you say 3 to 7, so we have a lower bound, upper bound and a mean so let's take the mean as a good representation.

Dr. John Morgan [00:32:22] Okay. Okay.

Dr. Ashraf Bastawros [00:32:22] Because you have like an imaging will have a tolerance for that. That's why you will never get one data point. You will get a distribution. So the first one will be the distribution of the grain or multiple of the grain size. Second question is how big a field of view that I should look at to show me uniqueness? And this is where it comes from, the interaction of the applied load with the material.

Dr. John Morgan [00:32:47] Right?

Dr. Ashraf Bastawros [00:32:48] So, for example, if I hold a pen and I bend it one way so the crack will be propagating in the direction of applying load. So you'll find that the way you hold the pen as we apply the load will give you a particular direction of that correct propagation.

Dr. John Morgan [00:33:02] Sure.

Dr. Ashraf Bastawros [00:33:03] So think of it. I have a pry tool and I'm wiggling it in the door of something. When it break, it will break. I can exactly to the guy who was holding it. And how is it to lose position?

Dr. John Morgan [00:33:13] Sure.

Dr. Ashraf Bastawros [00:33:13] So that'll give you what will call the river marks. Or is it directionality of the feature in a very different studies it wouldn't what we call it a fractography of your topology of fracture surfaces and that was done from mid 80s that they looked at fracture surfaces. How do I distinguish between ductile and brittle and how is the distribution of all those features? So there is a lens scale that always persist in the range of about ten grain size. Okay. So if I try to image my sample at the sub grain, you increase it, you increase it, you increase it and you see that the bigger the field of view, the roughness will increase to a level that will saturate. And that saturation level actually provides the characteristic roughness of the surface and is unique to every surface you touch. So when you told me how big of a field of view I should be, I should be up at the characteristic roughness that I should be able to catch is that and this is in the range of about ten grains and the smallest one should be is this too great? So your field of view should be at the maximum level or at least should be about ten grain in dimension.

Dr. John Morgan [00:34:26] Right? And that is yes. Okay. So that's not normally your field of view, but that's going to also inform your algorithms.

[00:34:33] Yes, so that is the field of view. I should get I should at least get ten grain in my field of view. Yeah. But also don't go to because I get 100 grain otherwise I'll not be able to distinguish any feature.

Dr. John Morgan [00:34:43] Sure. Okay.

Dr. Ashraf Bastawros [00:34:44] So that is the first rate. So if you give me an alloy or a fractured surface was five grain. So my field view should be about 50 micron.

Dr. John Morgan [00:34:51] Sure.

Dr. Ashraf Bastawros [00:34:53] Okay then if you give me 100 micron grain, my field we should be a thousand micron.

Dr. John Morgan [00:34:58] Yeah.

Dr. Ashraf Bastawros [00:34:58] So that is the first things. That is why I was telling you how we use tools. This microscope or this three dimensional interferometer it gives it topology. That is the first things we establish that at least we get. We need to get those thin grain in the field of view. Then once we take that, we take it into our spectral analysis and we divided or we try to get unique frequencies. So what we found the very first thing is that what we call it, river marks on the surface. So river marks are dictated by the applied load? Okay. Not to river marks would be the same. So river marks meaning that is like marks or patterns striation on the fracture surface. They're becoming how I applied the load on the surface.

Dr. John Morgan [00:35:42] Sure.

Dr. Ashraf Bastawros [00:35:43] So now again.

Dr. John Morgan [00:35:44] They're little gorges, basically. Yeah.

Dr. Ashraf Bastawros [00:35:47] So how are the controls are controlled by the grain size. The material resistance to fracture, which is intrinsic to the material and the external applied load. This combination of both (indiscernible), the statistical distribution of defect. So I have a random variable which is statistical distribution of defect material parameter which is grain size.

Dr. John Morgan [00:36:06] Yes.

Dr. Ashraf Bastawros [00:36:07] And resistance of material fracture is then a unique applied load. The combination of those will provide the uniqueness of this better.

Dr. John Morgan [00:36:15] Sure.

Dr. Ashraf Bastawros [00:36:16] Okay. And that is the premise of the uniqueness of how we really you characterize like a like I bring ten samples, break it in the same way the details of the fracture, topology, etc., scale would be different.

Dr. John Morgan [00:36:28] Okay.

Dr. Ashraf Bastawros [00:36:28] So this is the funny part. If I go down the scale, you look all looks the same. If I go up in the scale and I'll not see it, but around the scale, I'll be able to detect those unique features. It is this quite interesting. And this is will bring you back to the class and subclass characteristics and individuality.

Dr. John Morgan [00:36:47] Sure.

Dr. Ashraf Bastawros [00:36:48] Okay. So that that is the same language that you use in forensic. Yeah.

Dr. John Morgan [00:36:53] Or level one, two and three from John's perspective. But yeah.

Dr. Ashraf Bastawros [00:36:56] Oh level one, level two, level three. Yeah. And now I can bring use a feature mathematically founded to that level.

Dr. John Morgan [00:37:02] Sure. And the cool part about that in the end really is that it's based on the physics of what's going on.

Dr. Ashraf Bastawros [00:37:08] Exactly. Right.

Dr. John Morgan [00:37:09] You're not this isn't just like you're applying something that sounds right. You're fitting to it. You're actually looking at the physics of the material and then deriving your approach from that. So we put a lot down here on the podcast. So let me try to wrap up because people are going to be able to also get the archive of your presentation. There are a lot of different approaches to this and there are some folks who would take a look at what you're doing and they would say, No, no, no, no. You're throwing away a lot of data, actually.

Dr. Ashraf Bastawros [00:37:41] And the contrary, we are bringing a lot of data.

Dr. John Morgan [00:37:44] That's right.

Dr. Ashraf Bastawros [00:37:45] Like I would say that we are one of the groups that we are not throwing anything. What I was telling you, we have like a couple of things, you get the image we do the what we do the spectral analysis. Then we compare the, like, the two pairs together to get a number. Then we run it into a full statistical decision making process. Now, for every surface, we don't get one pair of images. Actually, we go all the way to nine pairs of images. So we make our decision based on the totality of the appearance of the surface, because maybe some part of it, like, you could have a big ridge or cliff that you get a lot of very hard is the analysis. But when you do it on a bigger number of images, you reduce the uncertainties in a big way.

Dr. John Morgan [00:38:31] And of course, in a in a forensic sample, you might be able to get, you know, 9 or 10 pieces across a very large geography, or you might only have a little fragment.

Dr. Ashraf Bastawros [00:38:39] But even little fragment, I'm telling you, like as the field of view we're doing, because the grains we are dealing with about 20 to 30 micron. So our field of view.

Dr. John Morgan [00:38:47] You don't need much.

Dr. Ashraf Bastawros [00:38:47] Right, it is 500 micron. So if I do ten images at best I am about to see in the (indiscernible). Yeah. Okay. So that is one then you will say, okay, but ten images. That is too much. If they are high quality from two images, they can get a decision. Like you will find that you did the decision, the probability and increasing the number of images. They didn't prove the probability. But if I get like, for example, three images, one pair of them is bad. That will start to influence. So that is why you say, okay, the safest level we have first to grade the image quality and give it a score. Then if it passes that score, you start your analysis. Don't make your decision on the lower number of data. Let's go back to the forensic scientist making logic puzzle comparison. So he never tried to say, okay, only two point methodology, take the whole fracture surface and bring many features. Yeah. Then we always say the following we have a match or inconclusive because the unmatched population I cannot characterize is huge. So we never tried to put exactly like if it doesn't match, what is the probability of no match because they don't have the dimensionality of the population. But when it is a match, it can give you the certainty of the match with the power of statistical learning tool that we added to it. It really become very easy to distinguish between many classes of material.

[00:40:08] Well, classic failure analysis would suggest that you should be able to tell the difference between types of breakage. Right. Between twisting versus pulling versus impact and that kind of thing. Ceramics are classic in that case. Very easy to determine in that regard.

Dr. Ashraf Bastawros [00:40:25] But actually, we beat it ourself to do a controlled experiment. Yeah, a control experiment, meaning ten pieces would pull it in the same way. And once we pulled it in the same way. But the uniqueness of the distribution of the effect dictated the topology to be different from one sample.

Dr. John Morgan [00:40:42] Sure.

Dr. Ashraf Bastawros [00:40:43] So we did it both ways. Is a controlled experiment and we check it. Or random expression. Random meaning just hold a knife and break it in any different way. The success of this project all relied on three prongs. First, we have John Vanderkolk who steered us in the right way. This is the right way to do it. This is the wrong way to do it if your forensic scientist. His help really guided us of how to generate dissent, what is acceptable, what is not acceptable. Then having a person like myself in the fracture, mechanics and materials. I know the background of a fracture process. And how is this influenced? Was it microstructure? How we do the right imaging? What is the scale to get the images? To that level that was great. But when I was doing alone and with the pseudo statistics, I was getting success rate like in discrimination, maybe 80%. 90%. Then once I start work with Bill Meeker and Rancho Maitre, they brought me to a very different level of how we really pose a proper statistical analysis and a proper handling of the data and the data size critical to make a decision. So I think having two three component integrated together resulted in where we are today.

Dr. John Morgan [00:41:56] The practitioner, the physicist, engineer, material scientist and the statistician, right.

Dr. Ashraf Bastawros [00:42:02] Maybe the only thing left is the lawyer.

Dr. John Morgan [00:42:06] Well, we'll keep them out of the scientific laboratory. They can argue out in court if they like.

Dr. Ashraf Bastawros [00:42:10] What I like here that we really know. If we really want to bring this one to the field, we know what we should teach them or how they should learn the trade to be able to really understand it or utilize it one way or another.

Dr. John Morgan [00:42:24] Excellent. Thank you so much, Dr. Bastawros. We appreciate having you on Just Science.

Dr. Ashraf Bastawros [00:42:28] Thank you.

Outro [00:42:32] Next week on Just Science, we will have Dr. Alicia Wilcox and Heidi Eldridge discuss factors that influence a jurors interpretation of expert testimony. Opinions or points of views expressed in this podcast represent a consensus of the authors and do not necessarily represent the official position or policies of its funding.