WaterJet Peening

ALEX CHILLMAN, PhD, Staff Mechanical Engineer and Research Platform Lead with Flow International, Inc., presented a paper on potential industrial applications for waterjet peening at the 2012 BHR Group conference. (See sidebar on the right.) Because *The Shot Peener* has been following the development of waterjet peening for industrial and medical applications, we were pleased to have the opportunity to interview Dr. Chillman regarding the emergence of waterjet peening as a mainstream solution for fatigue enhancement.

Alex Chillman, PhD, is a Staff Mechanical Engineer and Research Platform Lead for Flow International, Inc.

The Shot Peener: What are your job responsibilities at Flow International?

Dr. Chillman: I serve on a team that conducts application-focused research supporting "emerging applications." At Flow, emerging applications are opportunities that are outside the bounds of our typical abrasive waterjet shapecutting market. These applications may require new process and/or hardware development.

The Shot Peener: Why are you an advocate of waterjet peening?

Dr. Chillman: I had the opportunity to first evaluate the waterjet as a tool for peening from a scientific perspective, then from the commercial aspect. Many of the problems that can occur with traditional peening methods are minimized (or negated) with waterjet peening. Some examples:

- Surface dimpling with shot peening can lead to the need for secondary machining (thus removing the shallow subsurface layer containing the highest level of compressive residual stress). With waterjet peening, process conditions can be tailored so there is no notable change in surface topography.
- Concerns like rollover at geometric transitions are minimized. (Editor's note: Rollover is an edge condition in which

Potential of Waterjet Peening for Mainstream Industrial Applications

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ABSTRACT
While not yet been adopted as a mainstream solution for fatigue life enhancement, waterjet peening has been proven to provide an effective means for life improvement without inducing large scale degradation in surface topography. As opposed to many conventional peening processes that use solid particulates to induce compressive residual stresses in the subsurface layer, waterjet peening relies only on droplet impact. However, nozzle selection, jet manipulation methodologies, and waterjet process parameters must all be carefully selected for proper waterjet peening. In this paper, a brief look at the history of waterjet peening is presented, dating back to Salko's early discoveries that took place in the 1980s. Considerations for industrial application are presented, as well as case studies highlighting the potential benefits that exist when waterjet peening is properly employed.

INTRODUCTION
Enhancement of life for fatigue critical components is currently, and will remain, a key demand for industrial applications. Fatigue enhancement can occur due to surface finish improvement (reduce flaw sizes to slow crack initiation) as well as subsurface modification (induce compressive residual stress state to reduce mean alternating stress). When considering the latter of the two means of life improvement, traditional methods such as shot peening have gained wide-spread acceptance across a breadth of industrial families – spanning aerospace, automotive, and power industries to list a few.

Waterjet (WJ) peening, which relies on the breakdown of a high-velocity waterjet stream into a droplet field, has begun to emerge as an alternate means of subsurface modification; yet it seems it has not gained the acceptance of the traditional shot peening process. When discussing the rationale, reasons for waterjet peening lacking widespread acceptance may include:

- Many view waterjets as 'purely cutting and/or cleaning tools.'
- Lack of understanding how waterjets can be integrated and/or manipulated for industrial application.
- Minimal waterjet process know-how, which leads to fear of process drift or lack of control over the output surface modification.
- Industrial champions with vision to implement new technology.

In this paper, further definition to the waterjet tools as well as means of waterjet manipulation will be provided. A brief overview of past peening studies, dating back to 1984, will be discussed. Finally, a look at an industrial application and the benefits that were achieved with waterjet peening will be presented. The hope is that the material contained in this paper will help provide a continued step to understanding that waterjet peening is emerging from the realm of scientific discovery to a proven industrial solution.

Paper was presented at the PHR Group 21st International Conference on Water Jetting 2012. Reprinted with permission. Paper is available for download at www.shotpeener.com library.

the metal is deformed such that the edge starts to curl or fold over.)

- Waterjet is a flexible tool and can be easily integrated with a variety of motion systems, depending on the application.
- Waterjet peening can access tight spaces and internal cavities.
- Waterjet peening can be turned into a closed-loop process with proper filtration techniques, leading to reduced environmental impact.

The Shot Peener: You mentioned that waterjet peening can have a less of an impact on the environment than traditional shot peening methods. Obviously, water is easily recycled, but would it contain metal particles from the peened component?

Dr. Chillman: There are commercially available filtration systems that screen out particulates. With waterjet peening, there is often no material removal (depending on end goal of the application). To expand on this, let's consider two goals:

1) Waterjet peen a surface to induce residual stress without need for secondary machining (example: transmission shaft). In this case conditions would be selected to ensure no material erosion occurs while optimizing the compressive residual stress field.
2) Roughen a surface for a secondary coating while also inducing residual stress to offset surface roughening effects on fatigue performance. This transitions to a pure waterjet material removal application, and filtration of a closed-loop water supply would be required.

The Shot Peener: Energy consumption is another environmental consideration, as well as a cost factor. Does a waterjet peening process require less compressed air than conventional air blast peening?

Dr. Chillman: The compressed air requirements for waterjet peening are very low. The high-pressure water is created by either 1) a hydraulically powered intensifier pump or 2) a crankshaft- driven direct-drive triplex pump. Both pumps are documented at our website (www.flowwaterjet.com).

Compressed air is used to control the on/off valve (jet on/off function); however, there isn't a continual flow demand. Certain nozzle types do utilize an air flow to control the structure of the waterjet. For example, patent number 6,280,302 "Method and Apparatus for Fluidjet Formation" by Dr. Mohamed Hashish, with Flow International, covers a water-air jet nozzle.

The Shot Peener: In your paper, you write:

> Many peening applications require the precise uniform coverage of complex 3-dimensional surfaces. This requires a means of tool manipulation that is capable of meeting high levels of path accuracy. Previously, the need for high path accuracy would dictate that a Cartesian style 5-axis system should be required, which limited flexibility and often exhibited a high price point. With this type of system it is also difficult to have multiple waterjet nozzles working on the same part. Recent advancements in the accuracy levels (both path and position) of 6-axis robotic arms have led to a new viable alternative.
>
> The 6-axis robot provide high process flexibility, including ability to approach "top" and "bottom" sides of surface geometries with single fixturing. Also, various end effectors can be utilized, with quick change out at the flange. The robotic solution also allows for processing of large geometries, or local regions on a larger component, with the incorporation of a 7th axis linear rail.

You included a photo of a robotic waterjet cleaning cell in your paper (Figure 1). Could this technology be easily converted to peening equipment?

[1] The Shot Peener, Winter 2006 and Summer 2006.

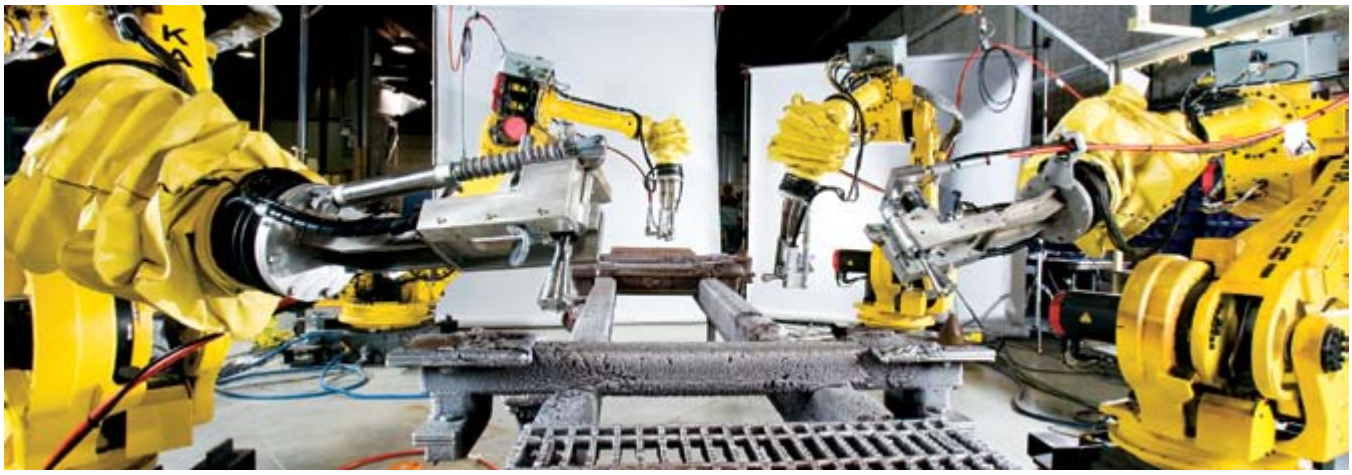

Figure 1. Robotic waterjet cleaning cell installed at a United States-based automotive facility.
PHOTO COURTESY OF FLOW INTERNATIONAL CORPORATION

Dr. Chillman: The configuration of the peening cell will be application driven, but both pieces of equipment would utilize the same pump and plumbing technologies. The main differences between cleaning and peening machines would be the nozzles and part fixturing methods, as well as potentials for enclosures and environmental controls.

The Shot Peener: *The Shot Peener* magazine has published the research of Dr. Dwayne Arola and Dr. Michael Jenkins[1]—both have studied waterjet peening for medical applications. What do you see as the benefits of waterjet peening to medical implant manufacturers?

Dr. Chillman: Some benefits are the following:

- The only processing medium with waterjet peening is water. There is no secondary material to risk material transfer/contamination of the surface.
- The nozzle design can be optimized for the application need. This may be broad covering jets (fan jets) to process a larger surface or a small focused jet to access a tight location. The nozzle design can be modified such that the optimal peening distance ranges from 0.1" up to +6" away from the nozzle.
- Surface texturing can be obtained with only water if desired.

The Shot Peener: Are private industries funding waterjet peening research?

Dr. Chillman: Yes, however, these companies prefer not to be identified for competitive reasons. Flow International has invested a significant amount of research into waterjet peening. Notable is the 1998 patent (Patent Number 5,778,713), covering many methods of waterjet peening.

The Shot Peener: Are any industries using waterjet peening now?

Dr. Chillman: Yes. While I can't go into detail, I know it is utilized in both automotive and aerospace today.

The Shot Peener: What will be the "tipping point" that makes waterjet peening a viable option for improving fatigue life?

Dr. Chillman: The tipping point will undoubtedly be dependent on industrial buy in and this comes back to the economics of the process as well as proven technical validity for a given application. As we all know, it's tough for a corporation to consider something new when current processes work, unless they can prove out the financial benefits. Many times the true financial study gets complicated when pre/post processing, capital equipment, power consumption, consumables, waste disposal, uptime, maintenance, etc., must all be factored in.