New Electronic Peening Intensity Sensor for Pneumatic Needle Peening Repair Tools

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Introduction

Controlled pneumatic needle peening is often used after blending surface damage to rebuild the residual compressive layer that is removed by the blend. Controlled pneumatic needle peening can be used to peen surfaces on assembled aircraft with minimal dismantling and minimal risk of Foreign Object Debris (FOD). This technique has the advantage of a small work-head to peen difficult to reach areas while maintaining optimal stand-off distance at all times.

Generating a saturation curve to find the Almen intensity with repair tools can be time consuming. Typically, generating a single saturation curve takes 15 minutes in the A scale and up to 1 hour or more in the lower N scale. The introduction of a new electronic sensor specifically developed for pneumatic needle peening promises to considerably simplify and shorten the intensity measurement and verification process. This sensor also facilitates user training on the equipment while being re-usable and save thousands of Almen strips which usually end up in the landfill.

Objectives

Evaluate the capability of an electronic peening intensity sensor for controlled pneumatic needle peening. Compare intensity values obtained by the sensor with methods currently used. Demonstrate potential time savings when using the sensor. Provide an example of the use of such a sensor for training purposes.

Pneumatic Needle Peening Tool Description

Manual peening repairs have been traditionally done using flapper peening [1], where tungsten carbide balls glued on a flexible flap, rotate and impact the surface. Due to the nature of the assembly of those flaps, the tungsten carbide balls tend to detach and fly off when they wear, causing potential FODs and greatly limiting peening applications. Therefore, a tool which eliminates this kind of risk was required. One such tool recently developed uses pneumatically actuated needles to perform peening without this risk. Figure 1 shows all the elements of this pneumatic needle peening tool, which features an embedded touch screen computer, a hand piece which hold the needles, an embedded electronic peening intensity sensor, as well as various cables and accessories, all stored in a portable case. [2]

The heart of operation of the pneumatic needle peening tool is located within the small work-head of the hand piece shown in Figure 1. Pneumatically actuated needles move back and forth to allow peening of a given surface. With flapper peening, the height of the flap/mandrel assembly depends on the operator's skill, thus introducing significant variability in the process. Additionally, flapper peening introduces semi-random impact angles and rubbing against the part, resulting in the typical surface linear roughness pattern seen after flapper peening. In the case of needle peening, the work head is rested against the surface and the needles impact perpendicularly to the surface, resulting in a much better surface finish.

Figure 1 Spiker-ES® Pneumatic Needle Peening tool kit (Left) and Work-head (Right)

The needles are made of tungsten carbide and the tips are rounded to a diameter similar to shot sizes seen in the industry. The tips can be rounded to specification, thus needles can be supplied with different tip diameters depending on what type of surface finish or intensity is required. To match the surface finish, needle tip diameter must match the shot used as much as possible. The tip of the needles used here is similar to cast shot S230 with a diameter of 0.600mm. The needles are encased inside the work-head, hereby eliminating the risk of FOD. The needle's up-and-down movement is measured continuously during operation with small position sensors inside the work-head. An alarm is triggered in the event of needle malfunction. The needles and caps wear down with time and higher intensity peening, which is why it is possible to replace them after many hours of use.

The controller features a touchscreen computer that monitors and controls various parameters as well as store operational data. The controller also features a saturation curve solver to calculate Almen intensity and provides pressure requirements for a given Almen intensity. In typical repairs, the operators use these features to quickly calculate and determine intensities required.

Applications scenarios range from aero engine blades, and wheels repairs, as well as structural components. A typical application on a difficult to reach area is illustrated in Figure 2.

Figure 2 Pneumatic Needle Peening Application on an engine blade

Peening Sensor Description

In the controller box, right under the touch screen, a newly developed electronic peening sensor allows measurement of needle peening intensity in near real-time. (Figure 3) This integrated device features a circular protective cover placed over a load cell. It is 42mm in diameter and is big enough to simulate the motion required for needle peening. The cover is reusable and can be replaced when necessary.

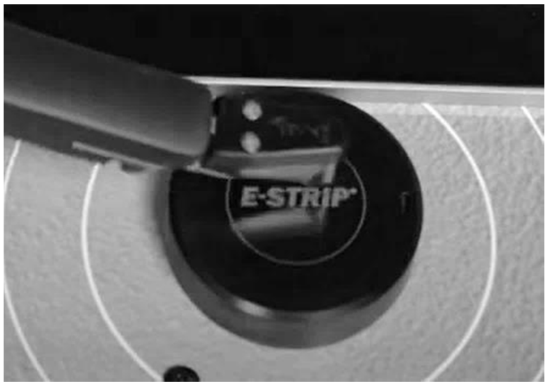


Figure 3 Embedded E-Strip® Electronic Intensity sensor

The sensor measures individual impacts of the needles and a custom algorithm calculates the average equivalent intensity after 10 seconds of continuous needle peening. The output is then displayed on the touch screen (figure 4), which allows for a quick read-out of the equivalent intensity.

8 Seconds Remaining

Equivalent Intensity
0.0044 (in) A

Figure 4 Touch screen interface – Peening in progress (Left), Equivalent Intensity result (Right)

Experimental Method

To test the sensor, needle peening is performed successively on Almen strips installed on a standard magnetic block and then on the electronic peening sensor. An average of 3 output values of the sensor was used to compare output results to the Almen intensities. These intensities are calculated using the onboard saturation curve solver which respects the SAE J2597 specification [3]. Different intensities were established by setting the pressures at 0.69bar, 1.38bar, 2.07bar, 2.76bar, 3.45bar, and 4.14bar for the A range intensities. For the N range, pressures were set to 0.69bar, 1.03bar, 1.38bar, and 2.07bar.

Peening was performed using the 4-needle work-head. Peening on the Almen strips is performed doing circular motions while covering the whole Almen strips and making sure the work-head is well rested against it. A set of 5 arc-height points is used to calculate the intensity using the integrated Shockform Saturation Curve Solver [4].

For the electronic peening sensor, the same circular movements are performed, but there is no need to move left or right since the sensor doesn't need to be covered due to its reusable nature. Almen intensity was determined according to the saturation curve, whereas the electronic intensity sensor displays the result after 10 seconds of continued peening on its surface, no matter the intensity level. Sensor output and Almen intensities are then compared for the intensity ranges and peening times are recorded and compared.

Results and Discussion

Pneumatic needle peening has been performed on a wide range of Almen intensities varying from the N scale to the A scale. It was then possible to correlate the outputs between the electronic peening sensor and Almen intensities, and plot the graphs seen in figure 5. The response of the sensor provides a good representation of Almen intensities. A perfect match would show all the points lie directly on the line. In these results, the goodness-of-fit measure R-square has a value of 0.984 in the N range and 0.997 in the A range.

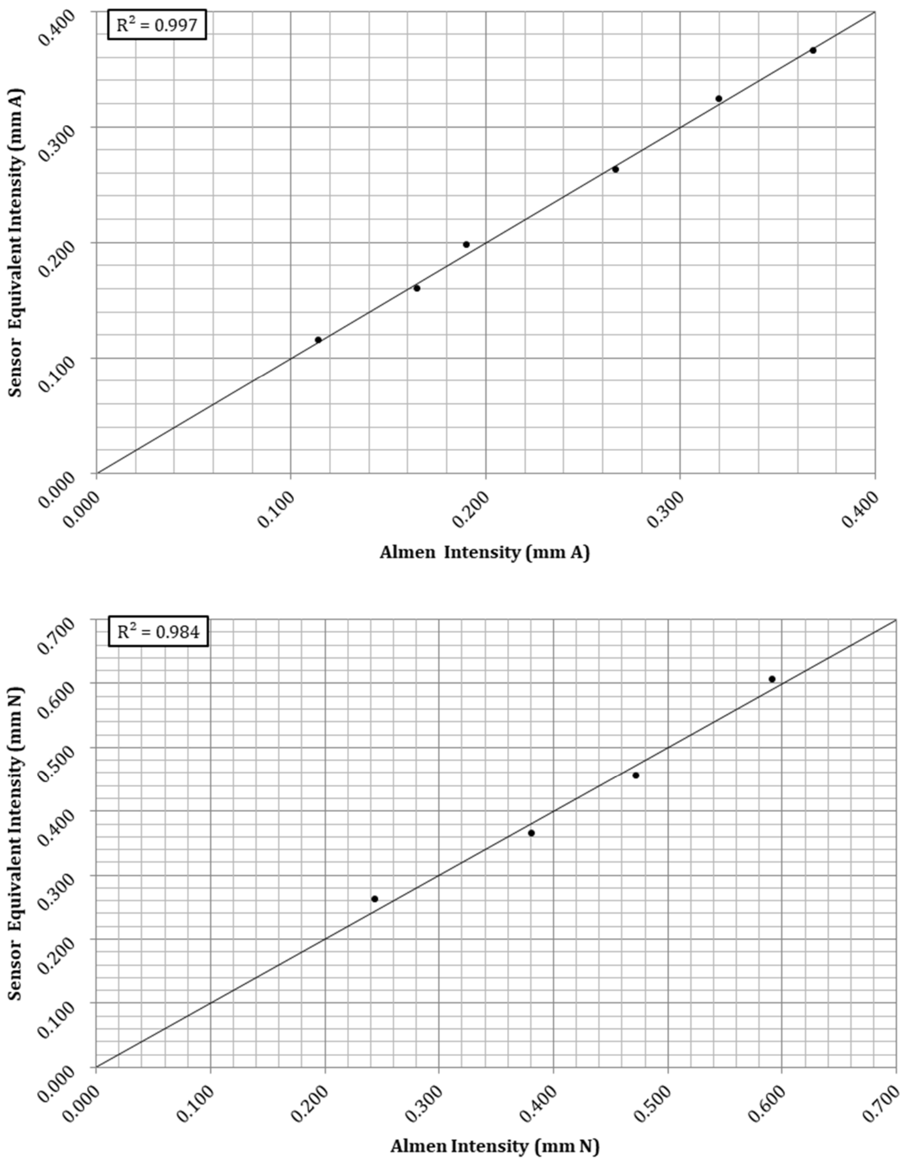
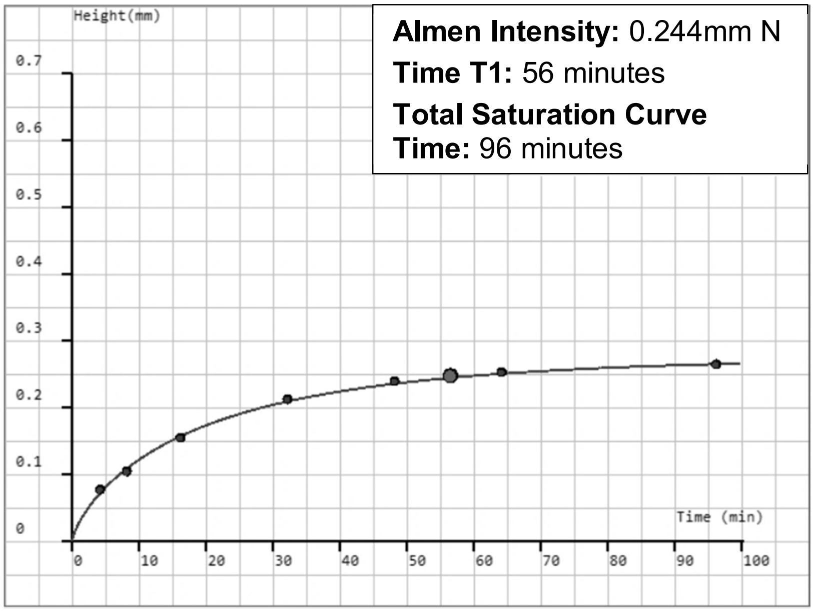


Figure 5 Sensor response plotted against Almen Intensity: N (Top) and A scale (Bottom)

A time study was also performed to see how much time could be saved using the sensor when determining intensity. At lower intensities in the N range, the longest total run time to complete a saturation curve was 96 minutes, or 1h36min., for a pressure of 0.69bar giving an Almen intensity of 0.244mm N (Figure 6). On the other hand, it took 10 seconds per test to verify the intensity with the electronic peening sensor.



Almen Intensity: 0.244mm N
Time T1: 56 minutes
Total Saturation Curve Time: 96 minutes

Figure 6 Saturation curve at 0.69bar.

Table 1 compares the total times for different intensity determination. Time savings range from 7.5 minutes at the high intensity in the A scale up to 95.5 minutes in the low N scale intensities. It becomes quite clear that the use of an electronic peening intensity sensor offers a important advantage when verifying intensities. In an organization, this could mean significant annual cost savings and increased productivity.

Table 1 Intensities and times results

Intensity range	Pressure (bar)	Almen intensity (mm)	Saturation time T1 (MM:SS)	Total Time taken to perform a full curve (MM:SS)	Sensor Equivalent intensity (mm)				Time taken on Sensor (MM:SS)	Time Saved (MM:SS)
					Test 1	Test 2	Test 3	Average		
N	0.689	**0.244**	56:09	96:00	0.265	0.254	0.266	**0.262**	00:30	95:30
	1.034	**0.381**	22:07	32:00	0.363	0.370	0.364	**0.366**	00:30	31:30
	1.379	**0.472**	07:42	16:00	0.459	0.452	0.457	**0.456**	00:30	15:30
	2.068	**0.592**	05:58	16:00	0.603	0.611	0.604	**0.606**	00:30	15:30
A	0.689	**0.114**	16:23	24:00	0.116	0.112	0.117	**0.115**	00:30	23:30
	1.379	**0.165**	06:32	12:00	0.158	0.161	0.159	**0.159**	00:30	11:30
	2.068	**0.191**	03:14	08:00	0.199	0.197	0.198	**0.198**	00:30	07:30
	2.758	**0.267**	03:28	08:00	0.261	0.265	0.261	**0.262**	00:30	07:30
	3.447	**0.320**	02:55	08:00	0.326	0.322	0.324	**0.324**	00:30	07:30
	4.137	**0.368**	02:21	08:00	0.374	0.360	0.364	**0.366**	00:30	07:30

In addition, using the sensor offers the possibility of reducing the complexity and risk of determining intensities since it is possible to very quickly determine if something is wrong in the process, such as the wrong setting or the wrong technique when needle peening. This is especially useful in the cases where users are not accustomed to the process. In a training environment for example, it becomes easy to adjust one's technique based on the output of the electronic peening intensity sensor and achieve optimal performance. For example, the sensor will show a low value if the tool is not held properly against the surface.

Conclusion

The paper introduced a new electronic peening intensity sensor for pneumatic needle peening repair tools. We showed the relationship between the output of the electronic peening intensity sensor and Almen intensity as well as the potential time saving for using the sensor in needle peening repair tools. It was determined that this new sensor responded closely to Almen strips while offering significant time savings. Furthermore, the sensor can help in the training a training environment to adjust one's technique and achieve optimal performance. A similar sensor will soon be available for flapper peening portable tools which would allow for the same advantages.

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