# The Saturation Point in accordance to the current SAE J443 – No problem for former processes?

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**Abstract**
The Almen strip and the herewith connected creation of a saturation curve is an important measuring method for defined and reproducible results within the controlled shot peening process of metal parts. Since 1952 when the first J443 "Procedures for Using Standard Shot Peening Almen Strip" [1] was issued the specification was several times adjusted till in June 2010 the current version [2] was issued. In this newest version the first time the Peening Intensity is a unique single point on a Computer Generated Shot Peening Saturation Curve following the SAE 2597 [3]. In all former specifications this definition was not exactly given or at least ambiguous. The present paper will first highlight the major changes in finding the Shot Peening Intensity in accordance to the former and latest version of the SAE-J443. In a further step it will demonstrate that by using the "former" and "new" the location of the saturation point on the saturation curve can be influenced an therefore eventually different parameters for the "same" Intensity could be used.

**Key Words**: Saturation Curve, Saturation Point, Peening Intensity, SAE-J443

## Introduction

The SAE-J443 describes the "Procedures for using Shot Peening Almen Strips". Major content of this specification is the determination procedure for the saturation curve which is needed to define the shot peening intensity. This paper describes the different historical steps in terms of determination the peening intensity from the first issue in 1952 [1] till the latest one in 2010 [2] when the first time a computer based procedure for an exactly defined intensity was introduced. In all SAE-J443 versions before the process to find the intensity was described more or less precisely but till 2010 the exact definition was still underlying a degree of uncertainty. The related consequences of this uncertainty and the possible consequences are in the focus of this paper.

## Definition of the Saturation Point/Intenisty – Historical development

In the Shot Peener Magazine [4] D. Kirk has already investigated the historical development of the SAE J443 from the first to the latest issue in general why the present paper will have a more detailed look on the development steps regarding the definition of the shot peening intensity and related possible consequences:

## The "old" SAE-J443 issues from the Year 1952 to 2003

The first SAE J443 was issued 1952 [1] and the shot peening intensity was described as a point where the saturation curve "flattens out" and furthermore could in some cases be "difficult to pick up" why this "requires some judgement".
This rather vague definition of the right intensity reading was not improved in the next issue from 1961 [5] when only some additions regarding intensity ranges for N, A and C strips and some minor graphical improvements have been introduced.

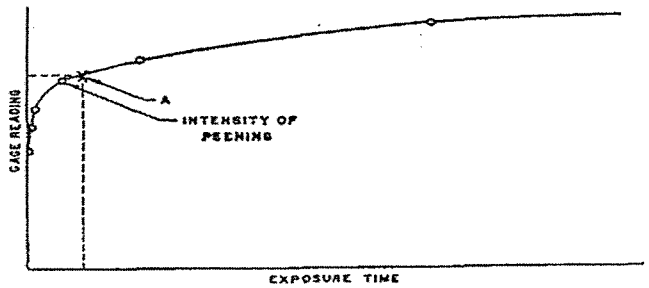


*Figure 1: J443:1952 - Intensity Determination Curve*

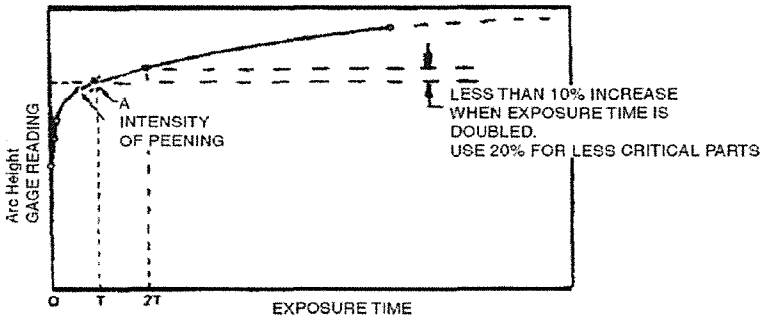


*Figure 2: J443:1984 - Intensity Determination Curve*

In the SAE J443 – Issue 1984 [6] first time the definition of exposure time T and 2T and a value of arc height increase between T and 2T was introduced. Important to recognize is the wording "less" for the arc height increase and that the "Intensity of Peening" seems to be a real measured Almen value. A bit confusing is the interpretation of the very left marking arrow which is marking a measuring point below the point A and also could mark the "Intensity of Peening".

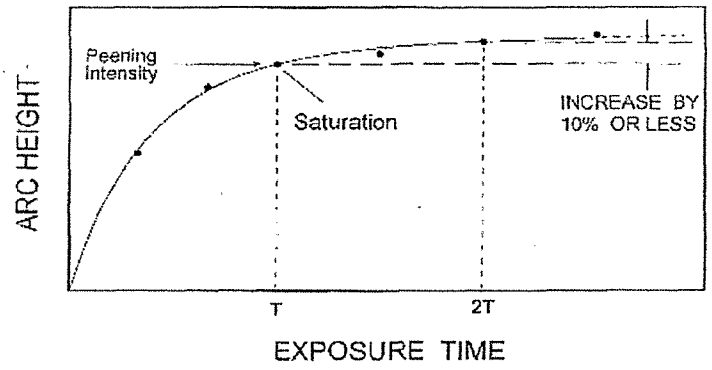


*Figure 3: J443:2003 - Intensity Determination Curve*

In the next issue of the SAE-J443 from 2003 [7], several changes appeared. The most important ones are first that the former „Intensity Determination Curve" was renamed to „Saturation Curve" and second the change in shape of the saturation curve.

The description to the curve stated as follows: "*Saturation has been attained when the "knee" of the curve is passed and increasingly longer periods of peening time are required for a measurable increase in test strip arc height. The location of the knee, saturation point shown in Figure 1* (here Fig. 3), *can be defined as* the first point *on the curve beyond which the arc height increases by 10% or less when the peening time is doubled.*"

First definition problem of this new version was that by introduction of the new curve in fact the so called "knee" was missing. Very important was the definition of the "Saturation" as the FIRST POINT on the curve where the arc height increases 10% by doubling the peening time Problem is that this actually exact definition stands in contradiction to the drawing in two points. First the drawing says still "increase by 10% or less" and second the marked point is shown as a real Almen value and not a virtual one.

Formerly explained problems gave still a lot of room for misinterpretation in using the specification "correctly".

**The "new" SAE-J443 2010** [1]

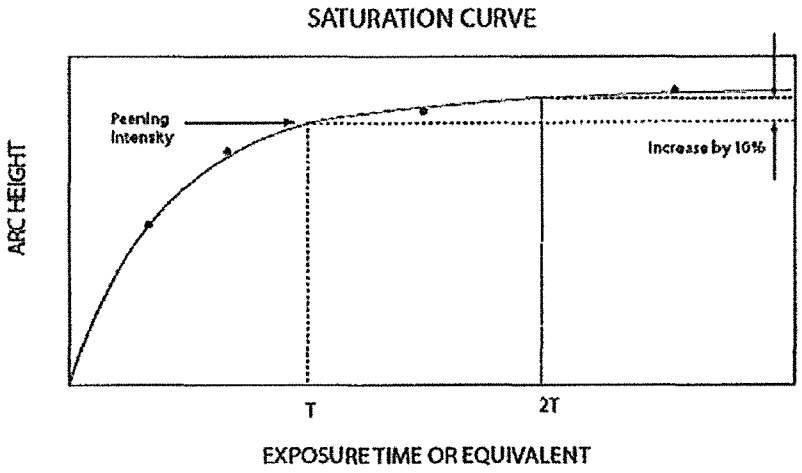


*Figure 4: J443:2010 - Saturation Curve*

In the latest issue of the SAE-J443 [1] the curve in comparison to the predecessor versions has not changed but all obscurities in terms of a single existing saturation point at exposure time T on the curve were clarified as follows:
*"The point on the curve where the arc height increases by 10% when the exposure time is doubled is declared to be the intensity. The exposure time associated with the intensity value is designated as T. The exposure time at which the arc height increases by 10% is designated as 2T. The use of computer generated saturation curves which comply with SAE J2597 is recommended."*
Additionally, following wording regarding the Saturation Curve was introduced:
*"Eliminate 'or less' from the arc height increase criteria so one and only one numeric answer can be derived from a given saturation curve. Use of 'or less' may allow extremely long exposure times with corresponding increases in arc heights to erroneously qualify as Intensity."*
This sentence already highlights a "common" error in the use of the older versions of the SAE-J443 and is underlined by a further addition:
*"It should be noted that Almen strips exposed for extended periods may exhibit arc heights significantly greater than the "intensity" value. This does not imply that extensively long duration peening treatments are in violation of intensity requirements. Intensity is a value derived from a saturation curve and is constant for a given set of machine parameters, regardless of peening time."*
Following the "former" versions of the SAE-J443 it was possible and sometimes "common practice" to use any point on the saturation curve which was fulfilling the rule "LESS than 10%" at double peening time – theoretically also points which were far away on the right hand side of the saturation curve.

**Experimental Procedure**
The experimental investigation was performed on a number of Almen strips type "A" made by two different suppliers whereas all of these fulfill the required specification. The shot peening machine used for all experiments is a nozzle machine type MIC 613 F3 which is equipped with a CNC control of all drives and the shot system including shot flow control by EI Electronics Magna Valves. The machine fulfills the AMS 2432D - Shot Peening, Computer Monitored [8]. The used computer based curve solver software is approved to the SAE-J2597 [3]. Shot peening was performed using cast steel shot of two different sizes - all in accordance to the AMS 2431/1 [9] and /2 [10]. To eliminate any effects from alternating distances or angles between the Almen Strip and the nozzle only one identical nozzle was used and was moving in exactly the same set-up over the fixed Almen strip.

**Explanation of used diagram type**
Normally saturation curves are presented as shown in Figure 5 based on linear x- and y-axis. In this paper the saturation curves and their appropriate growths rates (growth in % from one to the

next measured Almen value) are presented based on a logarithmic x-axis (cycles/peening time). Reason behind is that this way of visualization provides a better resolution of the growths rate especially during the first cycles and a better impression of the arc height increase even at higher numbers of cycles.

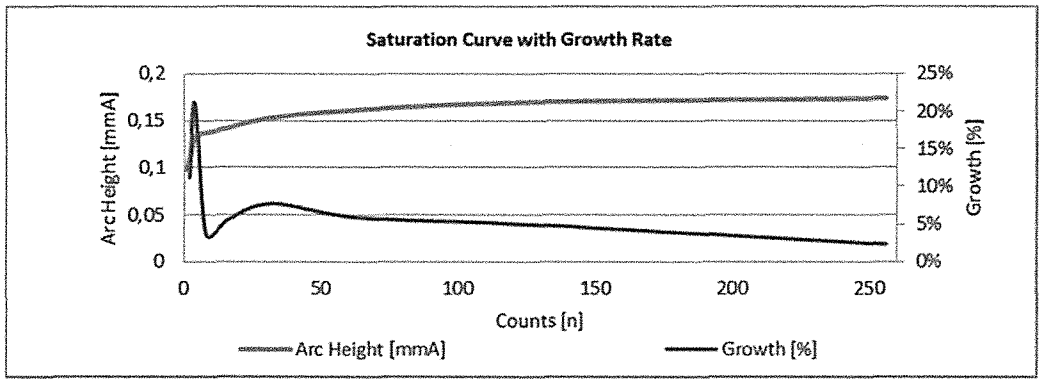


Figure 5: "Classic" saturation curve and growth rate with linear x-axis.

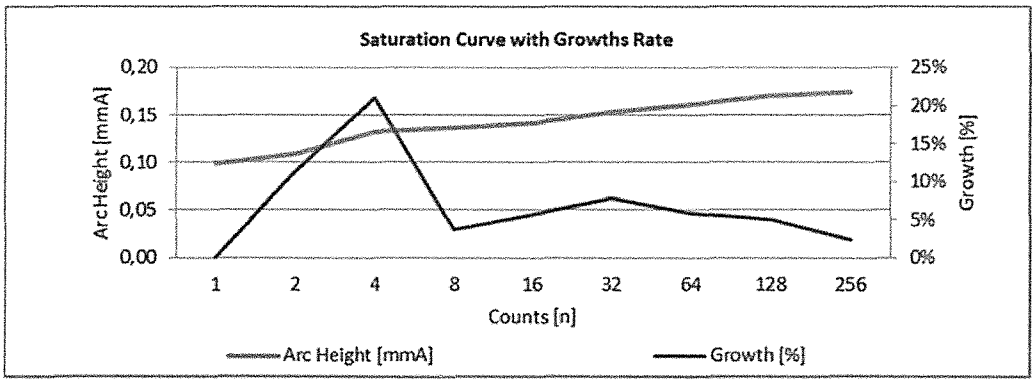


Figure 6: Saturation curve with logarithmic x-axis

## Experiment 1

Shot: ASH 110 / Air Pressure: 20 PSI (1,38 bar) / Shot Flow: 3kg/min

Within this first experiment 3 saturation curves were produced at different times with exactly the same set up of the shot peening machine. The Almen strips named A20-1 and A20-2 are from the same A20-3 from a second supplier.

On the left y-axis of Figure 7 the arc height in mmA and on the right handed y-axis the growths in percent from one arc height reading to the next is shown.

Interesting here is the "jumping" behavior of the growths rate of all used Almen strips which especially in the region around the 10% increase can lead to major differences in terms of intensity reading comparing the "old" and the "new" J443´s rules.

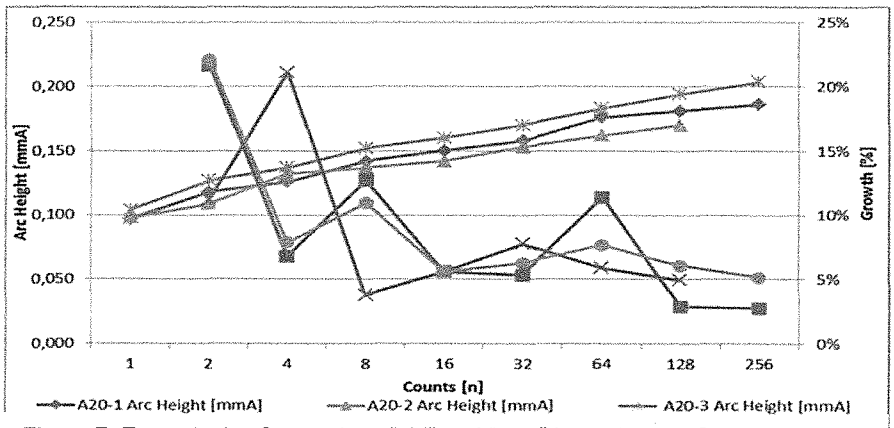


Figure 7. Example 1 – Comparison "old" and "new" Intensity and Counts

Clearly demonstrated is by the use of the logarithmic x-axis scale that "saturation" means only that the increase of arc height is slowing down – and not (maybe never?) stops completely - over the increasing number of counts.

| | A20-1 | | A20-2 | | A20-3 | |
|---|---|---|---|---|---|---|
| SAE J443 | Arc-Height [mmA] | Counts [n] | Arc-Height [mmA] | Counts [n] | Arc-Height [mmA] | Counts [n] |
| "new" | 0,134 | 4,33 | 0,126 | 3,46 | 0,142 | 4,09 |
| "old" | 0,118 | 2,00 | 0,132 | 4,00 | 0,127 | 2,00 |

Figure 8: Comparison "old" and "new" Intensity and

In accordance to the regulations of the "old" (issues before 2010) and the latest, "new" SAE-J443 the counts and intensity readings were taken (Fig. 8). For both versions the intensity readings are within the range of 0,118 and 0,142mmA which would still fulfill the allowable variances following the AMS 2430 [11].

**Experiment 2**

Shot: ASH 550 / Air Pressure: 20 PSI (1,38 bar) / Shot Flow: 3kg/min

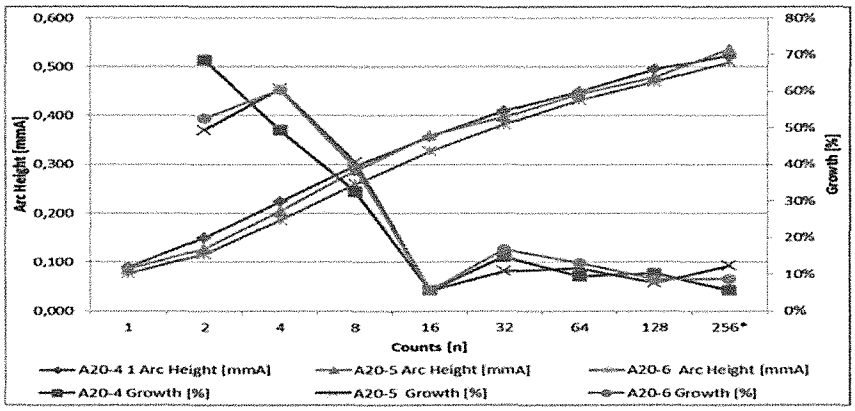


Figure 9: Example 2 – Comparison "old" and "new" Intensity and Counts

The second test run used again Almen strips type A and three saturation curves were produced with two sets of Almen strip from the same source A20-4, A20-5 and a third from a second source called A20-6. But this time a larger shot ASR550 was used.

Figure 9 shows a consistent trend of the arc height development and the related growths rate. Again a "jumping" behavior of the growths rate but this time smaller around the 10% border line is noticeable.

Based on the fact that all three saturation curves are showing a "less than 10%" increase at 8 counts following the "old" specification a reading was taken at this point in accordance to the "old" regulations.

Figure 10: Example 2 – Comparison "old" and "new" Intensity and Counts

| | A20-4 | | A20-5 | | A20-6 | |
|---|---|---|---|---|---|---|
| SAE J443 | Arc-Height [mmA] | Counts [T] | Arc-Height [mmA] | Counts [T] | Arc-Height [mmA] | Counts [T] |
| "new" | 0,413 | 31,37 | 0,404 | 30,79 | 0,407 | 42,84 |
| "old" | 0,297 | 8,00 | 0,287 | 8,00 | 0,259 | 8,00 |

Calculating the intensity with curve solver software in accordance to the "new" SAE-J443 reveals a significant different result. Compared the results from the "new" and the "old" specifications differences of more than 0,1mmA can be recognized which is far outside of all specified limits.

**Results and Discussion**

The latest SAE-J443 [1] with their definitions of the saturation curve procedure and the herewith indisputable definition of a single intensity by use of software based curve solver software was an urgently needed and very important step for the consistence and repeatable quality in controlled shot peening.

In this paper, it is demonstrated that by the use of the "old" or "new" specification significantly different intensity readings for the same saturation curve could be determined in both directions – too far "left" or "right" on the saturation curve. Too far "right" was more common by use of the "old" issues of the SAE-J443.

Another way around it might happen that by setting up a machine for the same intensity following the "old" or the "new" rule different parameters (e.g. air pressure) could be applied. This fact could lead to major different results by shot peening the same part in different locations following the "old" or "new" SAE-J443.

Therefore, the authors ask to overthink point 8.2.of the latest SAE-J443 [1] which states:

*"Existing process plans with intensity derived by "10% or less" or other approved methods may continue to be used"*

Following the argumentation above the word "may" should be replaced by "must" to avoid using a different than the originally approved process for a certain component!

**References**


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[7] SAE-J443, *Procedures for Using Standard Shot Peening Almen Strip, Jan. 1,* 2003
[8] SAE-AMS2432, *Shot Peening, Computer Monitored*, June 6, 2013
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