Variability Study of the Flapper Peening Process

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Introduction

Flapper peening is an important process to quickly re-peen small areas that have seen surface damage. It was developed more than 50 years ago and is extensively used on aerospace components such as landing gears, wing skins, helicopter hubs, etc.

In this article, statistical tools will be used to evaluate the impact of certain parameters on the flapper peening process variability. Once the important parameters are determined, the control of these parameters will be discussed.

Taguchi Method for Quality Engineering

Genichi Taguchi, a Japanese engineer and statistician, developed a very efficient statistical approach to determine the influence of parameters in a process (Ref. 1). Using his technique, only a limited number of trials are needed to determine which parameters are responsible for the process variability. With this information, it is possible to better control these important parameters thereby making the process more stable and robust.

The Taguchi method was used to study the parameters of the flapper peening process. Four main parameters were considered in the experiment. They are the rotation speed, the operator technique, the flap age and the magnet height. These parameters were selected because of their perceived influence on the process after discussions with several organizations using flapper peening on a daily basis. For each parameter, a high and a low value representative of a normal process was selected, as illustrated in Table 1.

Table 1

Parameter	Low=1	High=2
1) Rotation Speed	3900	4100
2) Operator Technique	Operator 1	Operator 2
3) Flap Age	New	Old
4) Magnet Height	Flush	0.125" High

An average rotational speed of 4000 rpm was selected for the experiment. This rpm usually gives an Almen intensity in the order of 0.010A. The low and the high values of ±100 rpm represent the acceptable rotational speed variability in the current military specification MIL-R-81841.

For the operator technique, two operators were selected for the experiment. They were both trained under a FAA certified course and were selected at random because of their availability at the time of the experiment. It is important to note that this parameter includes possible variability in the process for the height of the flap with respect to the part, for the coverage pattern and for the parallelism of the flap with respect to the part.

For the experiment, the flaps were either brand new, or with at least 30 minutes of previous peening. In both cases the flaps were not missing any tungsten carbine balls. These values were selected to represent some OEM specifications that require a flap to be changed after 30 minutes. The purpose was also to investigate the perception that flap preparation (removal of resin on tungsten carbide balls) can influence intensity and that flap effectiveness changes with usage time.

The last parameter selected is the height of the magnets inside the magnetic Almen block. This parameter was selected because of the perceived notion by some operators that changing the height of the magnet has an impact on

Table 2

Experiment	RPM A	Operator B	AxB	Flap C	AxC	AxD	Magnet D	Results Intensity
1	1	1	1	1	1	1	1	
2	1	1	1	2	2	2	2	
3	1	2	2	1	1	2	2	
4	1	2	2	2	2	1	1	
5	2	1	2	1	2	1	2	
6	2	1	2	2	1	2	1	
7	2	2	1	1	2	2	1	
8	2	2	1	2	1	1	2	

the Almen intensity. The height of the magnets can be easily changed by tightening of loosening the screws holding the magnets. For the experiment, the magnet height was selected as flush to the top of the magnetic block or allowed to move up to height of 0.125" above the surface of the block.

An L8 orthogonal array (Table 2 on page 38) was used to study the four main parameters and their interactions. The strength of the Taguchi method is that only eight trials need to be performed to determine the influence of all four parameters. These trials can be performed more than once to increase the confidence in the results. For each trial, the parameters can either have a low value equal to one (1) or a high value equal to two (2) as defined in Table 1.

For each trial, a complete five-point saturation curve was generated. From this saturation curve, the intensity is obtained using Dr. David Kirk's saturation curve solver (Ref. 2). The intensity is the result for each trial. Using these values, calculations are performed to determine the influence of each parameter.

Flapper Peening Analysis of Variance

The influence of the four parameters is presented in Figure 1. In increasing order of influence, we find the magnet height, the rotation speed, the flap age and the operator technique.

Magnet Height

The magnet height on the magnetic block has a negligible influence on the flapper peening process. As long as the magnets are flush with the surface or above, the location of the magnet shows negligible impact on the resulting intensity.

Flap Rotational Speed

The flap rotational speed is the third most important parameter in terms of influence on the process. This might be surprising since the intensity has a direct relationship with the rotational speed. The results actually show that the requirement to maintain the rotational speed at ±100 rpm is justified and ensures a low variability in the process.

It is often difficult to maintain constant air pressure in the shop and therefore maintaining ±100RPM capability can be a challenge. However, by using a closed-loop controller for the mandrel rotation speed we were able to maintain the required speeds automatically. Had this not been the case, then rotation speed would have been the dominant variance characteristic. It's easy to see that the next challenge is to have the operators properly trained and certified in the use of the equipment.

Flap Age

The results show that the condition of the flap can have a significant impact on the flapper peening process variability. New flaps, having a thin residue of resin on their surface, influence the effectiveness of the ball impact. This seemed to be a bigger influence than age of the flaps, whether they were new (resin removed) or had been in use for over 30 minutes.

The new flap variability can be further reduced by using the same flap for the complete duration of the job. Since flapper peening is mostly used on smaller surfaces, the complete job should require less than 30 minutes of peening.

Operator Technique

Operator technique has the most influence on the flapper peening process. Each operator holds and moves the tool differently which results in slight variations in flap height, parallelism to the surface and coverage patterns. Because of this, each operator has to generate his own saturation curve for each job. This ensures that the proper rotational speed is selected by each operator to obtain the required intensity.

This concept is further illustrated by Figure 2 which shows the flapper peening intensity variability due to different operators. For this study, 25 trained operators were asked to generate a five-point saturation curve at 4000 rpm using the Flapspeed™ controller for flapper peening.

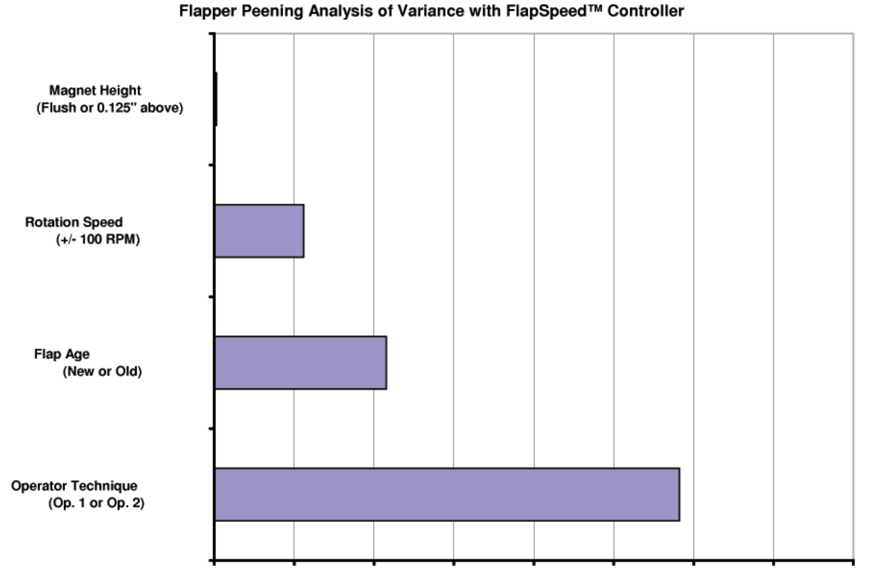

Figure 1 Influence of Parameters on the Flapper Peening Process

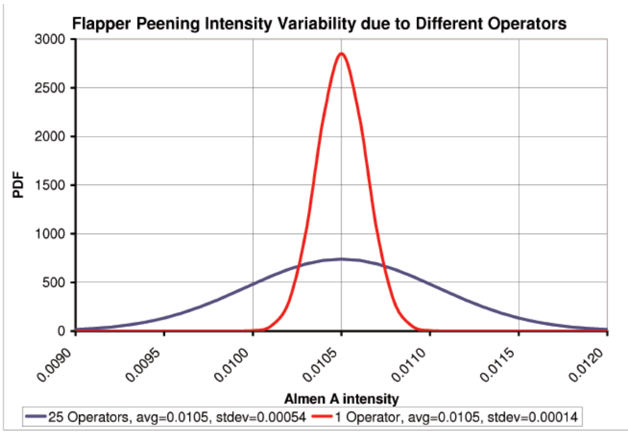

Figure 2

The FlapSpeed™ controller maintains the rotational speed at ±30 rpm thereby almost eliminating the variability due to rotational speed. The intensity was determined for each operator using Dr. David Kirk's saturation curve solver. The average intensity and standard deviation was determined for the 25 operators and plotted as the blue line in Figure 2. The red line illustrates the intensity variability when a single operator generates 10 saturation curves using the same settings.

The standard deviation for the single operator repeating his curves is almost one-third of the 25 different operators. This means that at ±3σ, the single operator would have experienced an intensity variability of less than ±0.0005A for a fixed setting while using different operators could bring that level to ±0.0015A.

Conclusion

The influence of four parameters on the flapper peening variability was studied. The analysis of variance revealed that the magnet height on the magnetic block had no significant influence on the process variability. The analysis showed that the flap rotational speed generated little variability as long as it was controlled within ±100 rpm.

The analysis also showed that the condition of the flap can introduce some variability in the process. This variability can be minimized by using a standardized procedure to clean the resin of the tungsten carbide balls, by using a single flap during the peening job and by keeping the duration of flapper peening jobs below 30 minutes.

The most influential parameter on the flapper peening variability is the operator. To minimize this variability, it is recommended that each operator generates his own saturation curve for each job. It was shown that a trained operator with proper control equipment can achieve a variability of less than +/-0.0005A when repeating the same job.

Overall, when carried out by trained operators with the proper control equipment, flapper peening is a very stable and repetitive process that is also fast, clean and easy.

References

1) Ross, J., Phillip, "Taguchi Techniques for Quality Engineering", McGraw-Hill Professional; 2nd edition, Aug 1 1995.
2) Kirk, Dr. D., "Almen Saturation Curve Solver", Microsoft Office 2003, Electronics Inc.,