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MANUAL PEENING WITH THE ROTARY FLAP PROCESS

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ABSTRACT

The use of Rotary Flap Peening for local area repeening of blemished surfaces is not new. It is often used to adjust the straightness or roundness of tubular parts. Because the process is manual, it is considered by some to be not very reliable or reproducible. Recent developments, however, demonstrate that when the process is adequately controlled it can be quite reliable and reproducible.

This paper describes a series of experiments that evaluated several critical factors for their effects on achieving consistent intensity values. The factors were: (1) flap rotation speed uniformity of three tool types, (2) flap standoff distance, (3) operator technique, (4) flap stiffness, (5) part cleanliness.

The author makes recommendations of critical equipment selection and operator techniques to achieve reliability levels approaching conventional shot peening processes.

KEY WORDS

Peening, Rotary flap peening, Roto peening, Flapper peening, Manual peening, Intensity control

CONCLUSIONS

Rotational speed of the tool and standoff distance controlled by operator technique are the major variables of intensity control. The type of rotary tool used has a major effect on control of flapper speed and hence intensity. Standoff distance has a significant effect on intensity control but a simple technique of allowing the rotating flap to "support itself" on its own reactive force against the surface being peened can provide a high degree of consistency. Determination of intensity from the saturation curve is another variable because it is a visual judgement of the Almen strip 100% coverage point. Achievement of the ± .001"A intensity control selected as the program goal can be achieved if the speed and standoff variables and intensity determination are controlled as described in this paper.

ROTARY FLAP PEENING DESCRIPTION

Rotary Flap Peening, also known as "Flapper Peening" or "Roto Peening", employs 1 mm tungsten carbide balls bonded to a flexible polymeric flap. The flap is held in the tip of a mandrel mounted in a rotary tool. Figure 1 illustrates a tool in proper peening position.

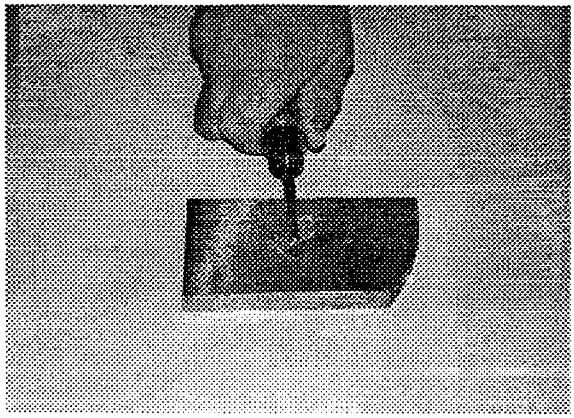

Figure 1. Flapper peen tool (electric grinder shown) held in position for peening.

APPLICABLE SPECIFICATION

U.S. Military specification MIL-R-81841 (Ref. 1) is the primary document used for process control, either by itself or as a reference in other specifications.

EXPERIMENTAL APPROACH

The approach taken in this study was to analyze the factors that cause intensity variations, in order to develop a control strategy. A goal of ± .001" A (±.025 mm A) intensity tolerance was selected, because this level is possible with a well controlled nozzle type shot peening process.

EQUIPMENT SELECTION

Three types of tools were evaluated. The first was an electric high-speed grinder with flexible drive shaft. The second was an air operated drill and the third was an air operated light weight grinder.

	Tool Type	Comments
	Electric grinder, high-speed with flexible drive shaft	Good speed control, medium torque, light weight
	Air drill, medium-speed	Best speed control, high torque, heavy weight
	Air grinder, high-speed	Poor speed control, very low torque, light weight

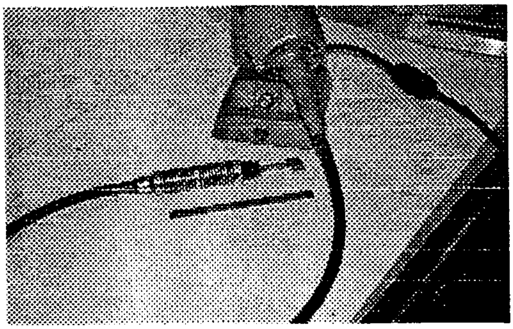

Figure 2. Electric grinder, Foredom High-speed with flexible drive shaft.

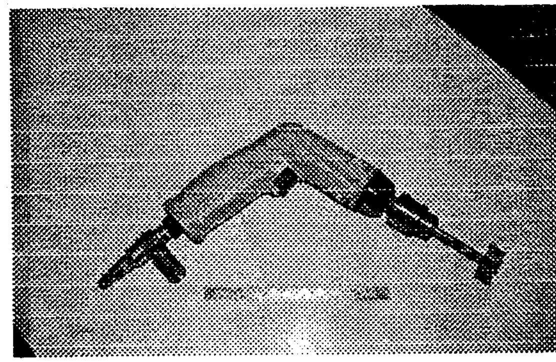

Figure 3. Air drill with manual speed adjustment located at bottom of handle.

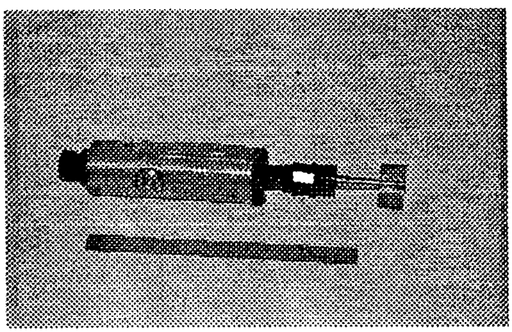

Figure 4. Air grinder high-speed light weight.

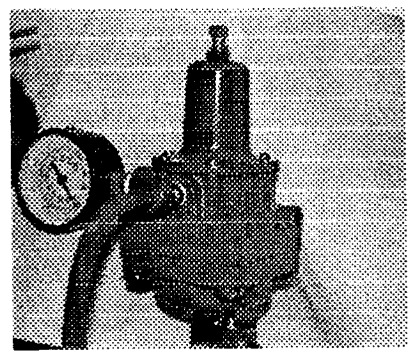

Figure 5. Air pressure regulator .

Another essential piece of equipment is a tachometer for measurement of rotational speed. Figure 6 shows a very easy to use hand held unit. This tachometer incorporates a light beam to illuminate a reflective tape applied to the tool chuck, which makes it easy to aim the tachometer with one hand while holding the tool in the other hand.

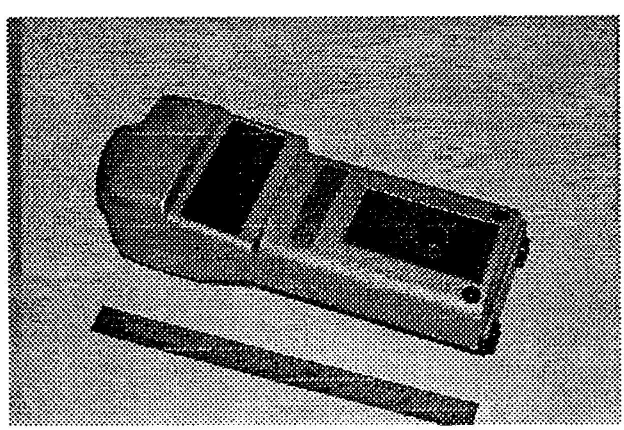

Figure 6. Tachometer.

INTENSITY DEPENDENCE ON FLAP SPEED

To determine the relationship between speed and intensity the 3M Roto Peen brochure (Ref. 2) curves shown in Figure 7 were used. The data for graph of Figure 8 was extracted from Figure 7, to show how much speed variation can be allowed if the intensity can only vary by .0005"A. Using the bottom two curves from Figure 7 the intensity increases by .005" for a change in speed of 1,000 rpm. The change from the second to the third curve is .0034", third to fourth is about .003" and the fourth to fifth curves about .0029". Therefore the tool must provide a speed consistency of approximately 100 rpm at low speed to 170 rpm at higher speeds in order to limit the peening intensity variation to .0005"A.

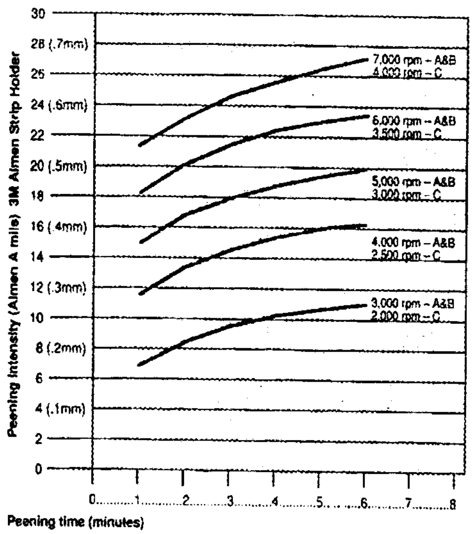

Figure 7. 3M Brochure saturation curves.

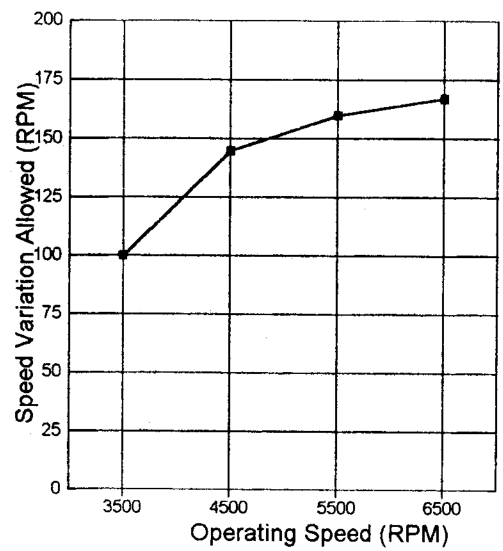

Figure 8. RPM variations for .0005A" intensity change.

TOOLS AND SPEED CONTROL EXPERIMENTS

The three tools were evaluated for control of speed. Several aspects of control were evaluated: (1) speed consistency during ten trials, (2) speed reduction under load and (3) speed reduction by other factors such as tool warmup or lubrication condition. A speed range of 3400-3800 was chosen because it corresponds to a midrange intensity near .010" A.

TABLE 1. Speed consistency tests (10 trials) under no-load conditions

Tool Type	Average Speed (rpm)	Std Deviation (rpm)
Electric grinder	3847	33.9
Air drill	3462	13.7
Air grinder	3685	33.7

TABLE 2. Speed consistency tests with .360" stand-off loading:

Tool	No Load Speed (rpm)	Load 1 Speed (rpm)	Speed Variation (rpm)
Electric grinder	3847	3817	30
Air drill	3462	3462	0
Air grinder	3685	3188	497

TABLE 3. Speed consistency tests with .090" stand-off loading:

Tool	No Load Speed (rpm)	Load 2 Speed (rpm)	Speed Variation (rpm)
Electric grinder	3868	3702	166
Air drill	3631	3616	15
Air grinder	no test	no test	no test

Equipment warmup and lubrication also affected tool performance. The electric grinder exhibited a gradual increase of speed of approximately 250 rpm during the first few minutes of operation. This was attributed to the heating of the lubrication in the long cable drive shaft which would reduce the friction and allow higher speed operation. The air drill would reduce its speed by approximately 50 RPM unless lubrication was applied after an hour or so.

The conclusion drawn from these tests is that the electric grinder provides marginal speed control, the air drill provides the best speed control, and the air grinder is not acceptable for this application.

SATURATION CURVES AND INTENSITY DETERMINATION

Peening intensity is determined by a system described in SAE J443 (Ref. 3) based upon a U.S. patent by J. O. Almen. Almen described using small steel test coupons that bow after being peened on only one side for increasing periods of time and the resulting curvature arc heights are plotted vs. time values. The resulting graph is called a "Saturation" Curve and it identifies the "peening intensity" of the blast stream.

For conventional shot peening the intensity is defined as the value of the arc height at the knee of the saturation curve. This knee is defined as the arc height or first point on the curve which, when the time is doubled, increases by only 10%.

Rotary flap peening uses a different criterion for determination of intensity. It is the arc height of the Almen strip when it is completely covered, or dimpled. This method is authorized in MIL-R-81841 (Ref. 1). The reason for this different criterion is the behavior of the magnetic strip holder used for rotary flap peening. The conventional strip holder cannot be used for flap peening because the restraining screws interfere with the flapper ball impacts. A set of magnets mounted in the holding block will keep the strip in position for peening but the magnetic attraction is not strong enough to prevent the strip from curving during peening. The saturation curve of a magnetically held strip does not exhibit the characteristic shape of conventional peening and the 10% rule cannot be applied. In addition the curvatures are greater in magnitude than with the conventional strip holder. Compensation is by reference to the universally recognized calibration curve in MIL-R-81841(Ref.1) as shown in Figure 9.

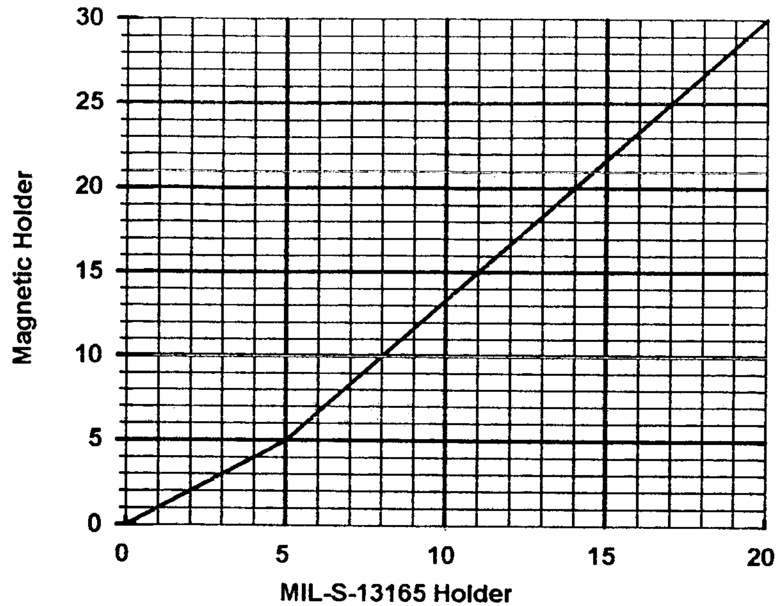

Figure 9 - Peening Intensity Conversion Curve

STANDOFF DISTANCE EFFECT ON INTENSITY

The setup shown in Figure 10 was used to determine the effect of standoff distance on intensity. It consisted of a "fence" which supported the mandrel and a "platform" to support the tool. Four fence heights were used to create standoffs (distance from mandrel to Almen strip) of 0.05", 0.10", 0.15" and 0.20". The platform height was adjusted to maintain the mandrel parallel to the strip. The standoffs were chosen to range from very low height (tool violently vibrating) to very high (unable to achieve required intensity).

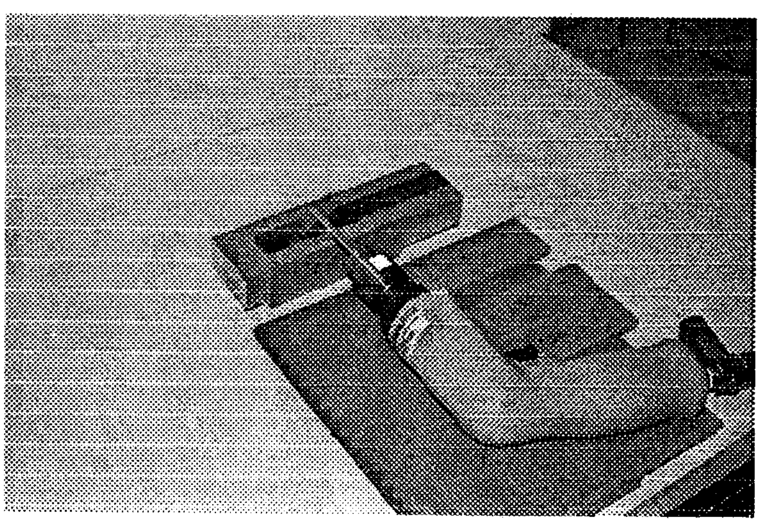

Figure 10. Standoff Distance Setup (Air drill shown)

A saturation curve was run at each of the four standoff distances. The curves are plotted in Figure 11. Two observations can be readily made. First, the intensity drops significantly when standoff increases above 0.15". The second observation is that the shape of the saturation curves and the intensity values of the other three standoffs are quite close together, including the 0.05" standoff at which the tool "vibrated".

TABLE 4. Resulting intensities using four standoff distances:

Standoff (inch)	Intensity (inch)	100% Coverage Time (minutes)
0.05	0.0124	2
0.10	0.0130	3
0.15	0.0118	4
0.20	0.0074	12

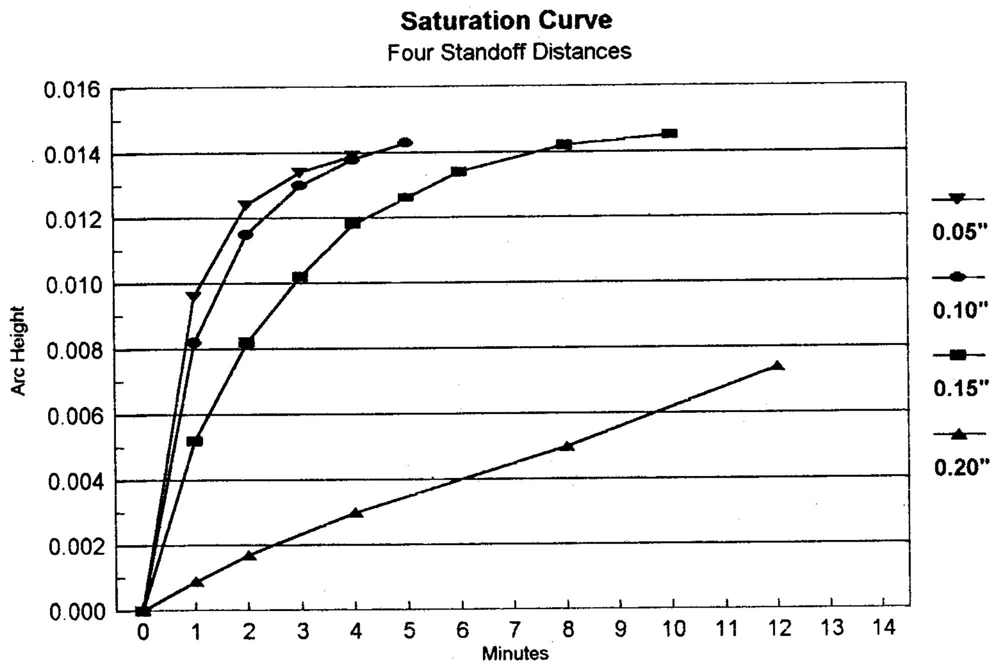

Figure 11. Saturation Curve with Four Standoff Distances

The much lower intensity determined for the .20" standoff is attributed to the reduction in transferred energy due to the angle of impact of the ball with the surface. Although some rubbing action instead of impacting might occur at larger standoff distances, examination of the peening dimples revealed that the dimples appeared round, as in the other cases, but much smaller in size. This smaller size would also explain the large increase in time for coverage since more dimples (small) would be required to cover the given area.

The author also observed that the standoff range .05"-.15" allowed a feeling of control of the process where the tool tended to "float" at a natural standoff height. However, at less than

.05" standoff the tool tended to vibrate but was still controllable. Conversely, at standoff heights above .015" the feedback was so slight that the author had very little feeling of control.

OPERATOR CONTROL OF STANDOFF DISTANCE AND INTENSITY

To assess the operator control factor, the author conducted a repetitive comparison experiment using the electric grinder and the air drill. Almen strips were peened in ten alternating campaigns of 1, 2, 3 and 4 minutes for each tool to generate saturation curves. Since only one Almen strip was used for all four points on each curve cumulative times were used to represent the saturation curve. Each successive time was simply one additional minute beyond the one before. In other words the 4 minute strip was peened a total of 4 minutes but had been measured at 1, 2 and 3 minutes previously. The same flap was used for both tools. Average tool speeds in the 3500-3600 RPM range were used. Tool RPM was measured before and after each one minute segment. The data are shown in TABLE 5.

TABLE 5. Arc Height and RPM Data Operator Control Test

							New Flap								Change Old to
Airtool Arc Heights	1	2	3	4	AVG	SDEV	5	6	7	8	9	10	AVG	SDEV	New Flap
1 min	8.4	8.5	8.0	8.4	8.3	0.2	7.7	7.5	7.0	7.9	6.8	7.3	7.4	0.4	1.0
2 min	11.3	11.5	11.0	11.1	11.2	0.2	11.2	10.7	9.8	10.7	10.5	10.4	10.6	0.5	0.7
3 min	12.5	12.8	13.1	12.4	12.7	0.3	12.7	12.3	11.7	11.9	12.3	12.1	12.2	0.4	0.5
4 min		13.5	13.8	13.2	13.5	0.3	13.5	13.2	12.7	12.9	13.2	12.9	13.1	0.3	0.4
			Average Std Dev all 10				0.3							Avg Change	0.7
Airtool RPM Before															
1 min	3475	3523	3560	3530	3522	36.2	3506	3521	3497	3497	3513	3470	3501	17.7	21
2 min	3546	3510	3541	3538	3534	16.2	3520	3497	3487	3475	3485	3475	3490	16.9	44
3 min	3569	3520	3551	3538	3545	20.7	3513	3489	3500	3481	3468		3490	17.3	54
4 min		3599	3537	3531	3556	37.6	3517	3501	3510	3502	3486	3488	3501	12.1	55
			Average Std Dev all 10				21.7							Avg Change	44
Airtool RPM After															
1 min	3542	3486	3510	3508	3512	23.1	3503	3495	3465	3483	3481	3465	3482	15.4	30
2 min	3563		3555	3536	3551	13.9	3505	3466	3494	3503	3496	3501	3494	14.4	57
3 min	3543	3580	3563	3540	3557	18.7	3530	3499	3510	3501	3486	3492	3503	15.5	54
4 min		3542	3564	3536	3547	14.7	3552	3508	3518	3516	3498	3488	3513	22.0	34
			Average Std Dev all 10				17.2							Avg Change	44
Foredom Arc Heights															
1 min	6.9	6.3	8.3	7.6	7.3	0.9	6.5	7.3	7.0	5.9	6.0	6.5	6.6	0.5	0.7
2 min	9.9	9.5	12.0	10.8	10.6	1.1	9.8	10.1	9.9	8.7	9.6	9.8	9.7	0.5	0.9
3 min	11.8	11.3	13.2	12.1	12.1	0.8	11.0	11.6	11.6	10.4	11.2	11.4	11.2	0.5	0.9
4 min	12.8	12.5	14.0	12.9	13.1	0.7	11.8	12.8	12.6	11.4	12.3	12.0	12.2	0.5	0.9
			Average Std Dev all 10				0.7							Avg Change	0.9
Foredom RPM Before															
1 min	3501	3561	3603	3588	3563	45.0	3510	3567	3478	3515	3488	3587	3524	43.6	39
2 min	3538	3602	3715	3632	3622	73.5	3462	3565	3601	3428	3565	3606	3538	74.7	84
3 min	3580	3598	3620	3582	3595	18.5	3360	3605	3582	3445	3546	3558	3516	94.1	79
4 min	3464	3608	3640	3548	3565	77.4	3336	3593	3604	3536	3625	3556	3542	105.8	23
			Average Std Dev all 10				66.6							Avg Change	56
Foredom RPM After															
1 min	3550	3598	3701	3607	3614	63.2	3553	3606	3612	3569	3606	3615	3594	25.9	21
2 min	3569	3595	3810	3741	3679	115.7	3581	3586	3635	3548	3579	3697	3604	53.3	74
3 min	3601	3700	3767	3565	3658	92.3	3402	3603	3591	3604	3601	3557	3560	79.2	99
4 min	3601	3668	3740	3610	3655	64.1	3452	3644	3603	3583	3606	3630	3586	69.2	68
			Average Std Dev all 10				70.4							Avg Change	65

The following numerical observations were made:

(1) Standard deviations of speed:
~70 RPM for the electric grinder with three speed adjustments required
~20 RPM for the air drill with no speed adjustments required
(2) Standard deviation of arc heights:
0.0007" for the electric grinder (probably due to speed variations.)
0.0004" for the air drill
(3) The new flap used in trials 5-10 resulted in average arc height reduction of .0008". The incidental lower speeds of 44 to 65 RPM would account for only 10% of that reduction. It is postulated that the new flap, being stiffer, may have increased the standoff distance and thereby reduced the arc heights in the same manner that intentionally increasing the standoff distance would reduce the arc height.
(4) The electric grinder required several minutes of warmup time to stabilize its speed and several (small) speed adjustments were needed after warmup.

Additional judgmental observations were made:

(1) The most comfortable and easiest to maintain standoff distance was obtained by allowing the rotating flap to seek equilibrium and "support itself" on its own reaction force against the surface being peened. Lower standoffs produced a rattling vibration feedback. Too high standoffs provided less feedback and therefore loss of operator feel of positional control.
(2) The electric grinder, because it is lighter, was easier to maintain at the self support standoff distance.
(3) The air drill, with its heavier weight, resulted in a smaller standoff distance which would more easily produce the rattling vibration but no loss of control.

ALMEN STRIP COVERAGE DETERMINATION

Determining dimpling coverage of an Almen strip involves subjective judgement, especially as the coverage approaches 100%. . Magnifier loupes of 10X power are typically used for inspection but the top lighted 20X binocular microscope pictured in Figure 12 makes the task easier and more reliable.

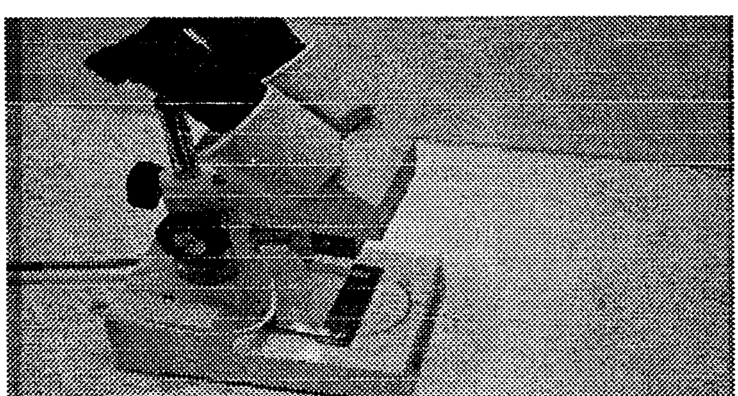

Figure 12. Top Lighted 20X Binocular Microscope

ALMEN STRIP CLEANLINESS EFFECT ON INTENSITY

The effect of surface cleanliness was examined using a fluorescent tracer, commonly used in conventional peening for coverage determination, and also a light lubricating oil. The tracer was applied only at the beginning of the complete 1, 2, 3, 4 minute cycle. The lubricating oil was applied before each one minute segment. Surprising to the author, no reduction in arc height was observed with either substance. This is a very useful result because it not only relieves the rotary peening operator of the necessity for absolute cleanliness of a part, but may also allow the use of fluorescent tracer for helping to determine the Almen strip 100% coverage intensity point.

REFERENCES

1. Military Specification - MIL-R-81841 – "Rotary Flap Peening of Metal Parts"
2. 3M Abrasives Systems Div. St Paul, MN, USA - "Roto Peen Flap Assemblies TC 330" brochure
3. SAE Specification – J443 – "Procedures for Using Standard Shot Peening Test Strip"