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DESIGN AND DEVELOPMENT OF PNEUMATIC INDUCTION TYPE BALL PEENING NOZZLE

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ABSTRACT

Chronological development of induction or syphonic shot peening nozzle to ball peening nozzle was reported. Syphonic ball peening is clean and more effective for highly stressed components like steam turbine blades. Continuous and uniform peening was possible with smaller quantity of bearing balls. This process is more economical than shot peening. The relative position and geometry of primary nozzle, mixing chamber, orifice diameter and secondary nozzles were experimentally evaluated. Optimum design of syphonic ball peening nozzle was reported based on experimental evaluations.

KEY WORDS

Shot peening, Ball peening, Syphonic nozzles, Mixing chamber, Primary nozzle and Secondary nozzle.

INTRODUCTION

Syphonic ball peening is appropriate process for improving fatigue strength of highly stressed components like large steam turbine blades. The forged steel balls are perfectly round, clean and more uniform in size. Breakage of the ball is also likely to be less. It successfully produce the surface condition required for steam turbine blade (1). Syphonic ball peening system provides uniform peening besides being simple, clean and economic.

In induction or syphonic peening system the shots are aspired into the vacuum zone created by the sudden expansion of compressed air and kinetic energy is imparted to them. In 1981 convergent-divergent single nozzle was used for this purpose (2). Shot suction opening at the throat diameter where vacuum was created. But the model did not work because the vacuum created was not appreciable. The compressibility of the air which gave local rise in pressure and as a result sufficient shots did not aspired at the throat of primary nozzle. Then the design was modified and two nozzles were used. The first nozzle or the Primary nozzle was used to create sufficient vacuum for shot suction and the second or the Secondary nozzle was used to give appropriate kinetic energy to them. Between primary and secondary nozzle adequate passage was provided for suction and proper mixing of shot with air. Other investigators have also reported similar type of nozzle profiles (3).

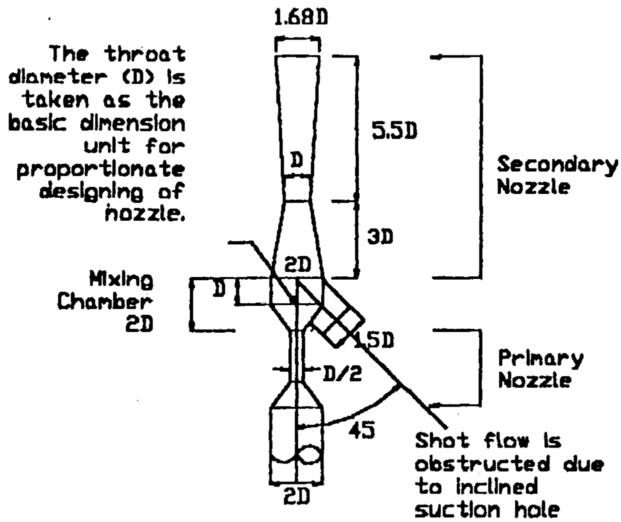


Fig.1 PROPORTION OF SYPHONIC SHOT PEENING NOZZLE DEVELOPED

The proportionate dimensions of shot peening nozzle with throat diameter up to 6mm was reported as shown in Fig.1 (4). In the present investigation and systematic experimentation on the ball peening nozzles have shown that the dimension of the balls used had more crucial role in the designing of the same. In this paper some important aspects like shape of primary nozzle, secondary nozzle and mixing chamber, suction holes location, mass flow rate, air consumption in induction type ball peening system were experimentally evaluated and the results of different modifications were presented.

DESIGN OF BALL PEENING NOZZLE

The conventional syphonic nozzle when used for ball peening more peening time was required to achieve same peening intensity. The proportionate dimension of shot peening nozzle was used to design the ball peening nozzle (5). In that design the diameter of throat of the primary nozzle 'd' was taken as the basic dimension. In terms of 'd' the other parameters were expressed. It was found that as the balls have much greater diameter and mass than shots for some particular dimensions the diameter of balls became important parameter. If this parameter was not taken in account then the flow of balls was found to be restricted initially.

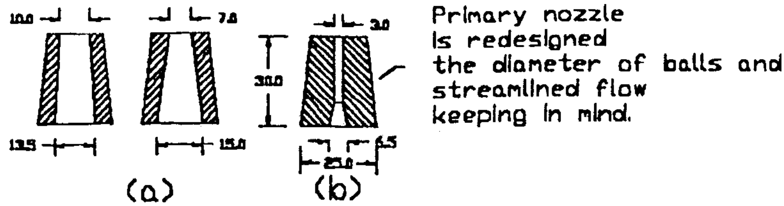


Fig.2 PRIMARY NOZZLES

PRIMARY NOZZLE

The standard diameter of the hose was reduced in the nipple and the primary nozzle to an optimum diameter. It was found that if the diameter is more than ball diameter the ball slides into the hose when the system is not operating Fig.2(a). If large number of balls are disposed in the hose the system does not work. These problem does not arises in case of syphonic shot peening system due to inclined induction passage. And somehow if shots come into the hose when the system is started being light weight shots are carried out with compressed air. The primary nozzle was redesigned keeping the diameter of the shot and streamline motion in mind. In the primary nozzle used for 1/8-inch steel ball the 6.5mm diameter was converged to 3mm diameter and then it was kept constant through out the length Fig.2(b). This design streamlined the flow and the model has good performance and coverage.

MIXING CHAMBER

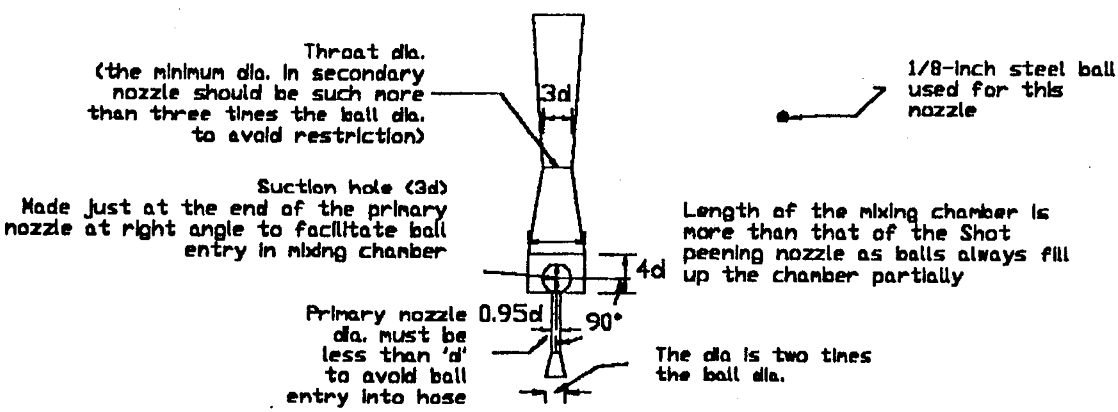


Fig.3 PROPORTIONATE DESIGN OF THE BALL PEENING NOZZLE

The dia. of the ball (d) is taken as the basic dimension unit for proportionate designing of the nozzle.

The shot peening nozzle did not give good performance with 3/16-inch or higher ball size. To suck in the higher mass of ball through a inclined suction hole a very high pressure drop was required. In the shot peening nozzle the suction hole was inclined at 45° with the axis of the nozzle. In the new experimental design the suction was made at 90° with the axis of the same Fig.3. It helped the ball to slide in the mixing chamber. The outside wall of the mixing chamber was rounded to use the ball head and to help them glide in Fig.4(a). To facilitate the balls suction in addition to the rounded outside profile of the mixing chamber the suction hole could be made converging by grinding them. Better result was obtained after these modifications. Some balls are always present in the chamber and uniform flow was obtained without any additional mass flow control device.

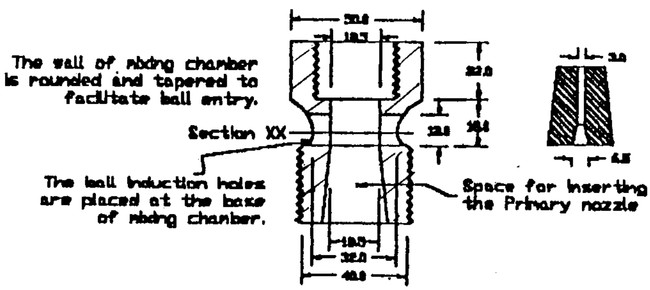


Fig.4(a)

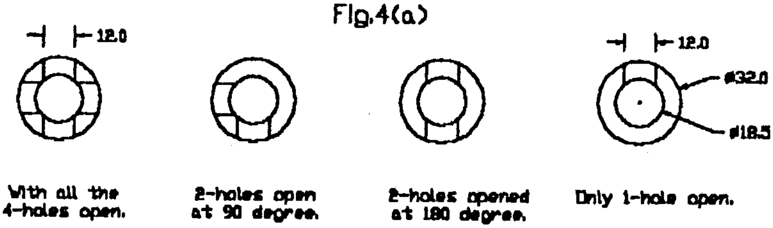


Fig.4(b) MIXING CHAMBER WITH DIFFERENT COMBINATIONS OF HOLES.

Different combination of mixing chamber length and number of openings are used to reach the optimum design. We have used 20mm and 15mm mixing chamber length with different secondary nozzle combination. When all the four suction holes were kept open air started come out rather more balls were aspired in. The flow in the mixing chamber became turbulent. Mixing chamber with two suction holes open gave better result. The detail description of experiments and the results obtained are discussed later in Mass flow behavior.

In our experimental model 4 suction holes were made at perpendicular to each other. Combination of holes were closed as shown in Fig.4(b) and reading for mass flow were taken at 5.0kgf/cm^2 to 6.0kgf/cm^2. It was found that the numbers or different position, directions of suction openings did not have much appreciable effect on mass flow rate or the velocity of the balls. But the diameter of the suction hole played important role in mass flow rate. Better results were obtained with 1/8-inch ball when the suction diameter was increased from 9.5mm to 12.5mm. While with 3/16-inch it was still low. For easy suction and better slide in action of balls the diameter of the hole must be at least 3 times the diameter of the ball used.

Part of the mixing chamber always being filled with balls the height of the mixing chamber must be kept more compare to shot peening mixing chamber. Experimentally it was found that if the height was less than 4 times the ball diameter the mass flow rate decreases. Drastic change from mixing chamber diameter to secondary nozzle entrance diameter also gave poorer performance. For different combinations it were observed if the nozzle diameters were too less compare to 18.5mm diameter of the mixing chamber then irrotion takes place in the nozzle and the flow of media was restricted.

SECONDARY NOZZLE

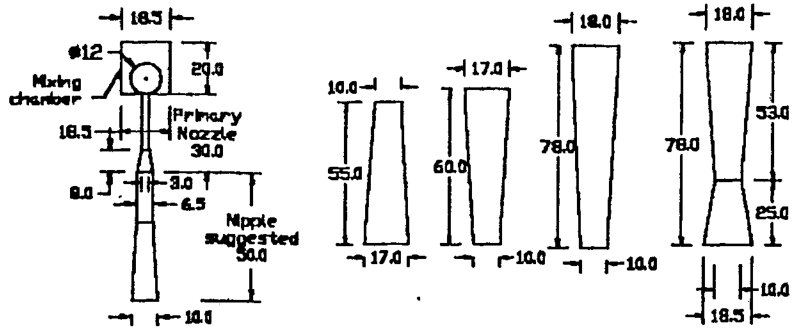
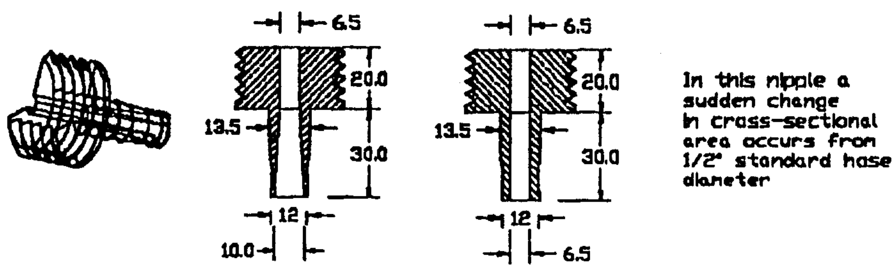


Fig.5 DIFFERENT COMPONENTS AND COMBINATIONS OF BALL PEENING NOZZLE

Different combinations of converging, diverging, converging-diverging nozzles Fig.5 were used for different experimental setup to plot the mass flow rate vs pressure curves and the peening intensity vs pressure curves. Appropriate mass flow rate and appropriate velocity is needed for uniform peening and residual stress distribution. Too high velocity produces irrosion and high mass flow rate gives very low velocity subsequently low coverage and low intensity.

For 3/16-inch ball the mass flow rate and velocity both were less than those for ball 1/8-inch. Beside the other reasons the minimum diameter in the secondary nozzle seemed to have an effect on the results. If the diameter was less than 3 times the ball diameter due to restriction both the mass flow rate and velocity were reduced.

HOSE AND NIPPLE

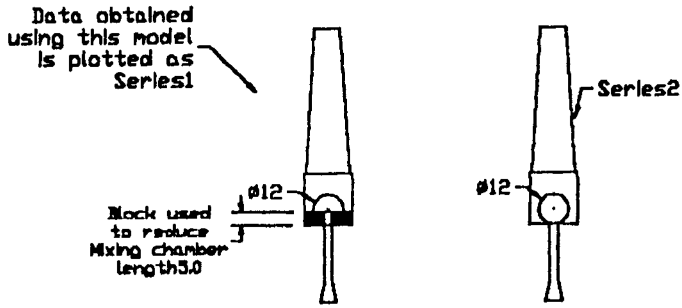


NIPPLE SUGGESTED PREVIOUS ONE

Fig.6

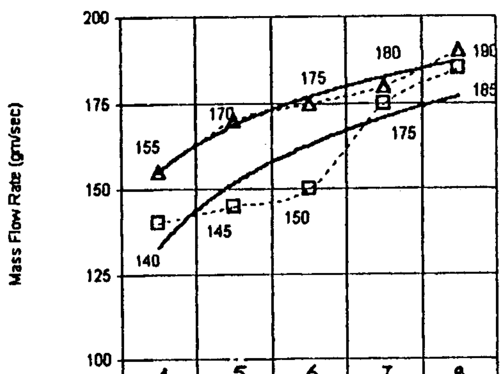
The 1/2-inch hose were used for supplying 0.676cu.m/min. According to the diameter of the hose used the nipple was redesigned. A converging taper has been suggested which will reduce from, 10mm I.D. to 6.5mm Fig.6. Thus sudden change in supply diameter and head loss in air flow was avoided. It was found that for 3/16-inch diameter ball 25% more discharge required accordingly the standard hose diameter and nipple is to be used.

MASS FLOW BEHAVIOUR



.CONVERGENT NOZZLE (SET-1)
Fig.7(a)

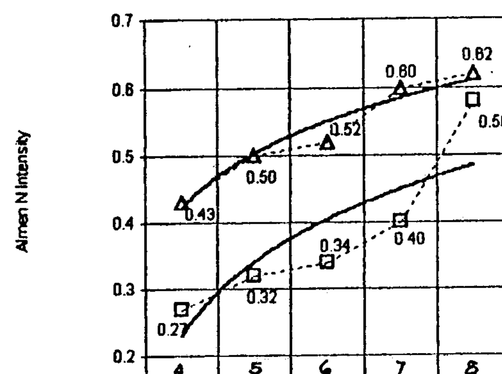
MASS FLOW RATE vs PRESSURE (set 1)



	4	5	6	7	8
Series1	140	145	150	175	185
Series2	155	170	175	180	190

—— Log. (Series2)
—— Log. (Series1)
Pressure (kgf/sq. cm)

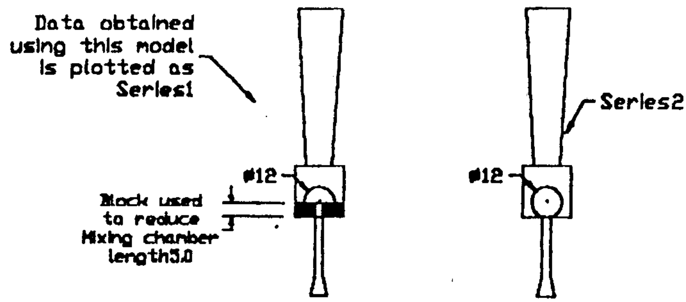
ALMEN N INTENSITY vs PRESSURE (set 1)



	4	5	6	7	8
Series1	0.27	0.32	0.34	0.4	0.58
Series2	0.43	0.5	0.52	0.6	0.62

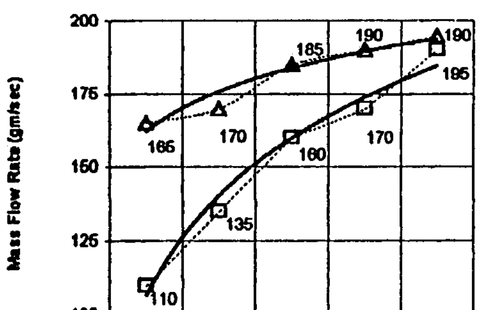
—— Log. (Series2)
—— Log. (Series1)
Pressure (kgf/sq. cm)

Average mass flow at different compressor pressure for various proposed models were plotted as shown in figure. To investigate the cause of drooping in mass flow, thin paper flaps, were placed (being pasted at one end on the top of the holes) just infront of the four suction holes. Compressed air was allowed to flow at different pressure without balls surrounding the the nozzle. It was observed that at higher pressure ranged beyond the limits indicated by mass flow curves there was turbulence in air flow and part of the compressed air has started flowing out of side suction holes. Obviously the suction was reduced at the mixing chamber and that caused reduction in mass flow. Further trials were conducted to find out the behavior of air flow with varying size of mixing chamber by keeping 1-hole, 2-holes, 3- holes, 4-holes opened successively. The results show that maximum mass flow could be obtained with two holes open at the mixing chamber at all pressure levels tested.



SMALLER DIVERGENT NOZZLE (SET-2)
Fig.7(b)

MASS FLOW RATE vs PRESSURE (set 2)

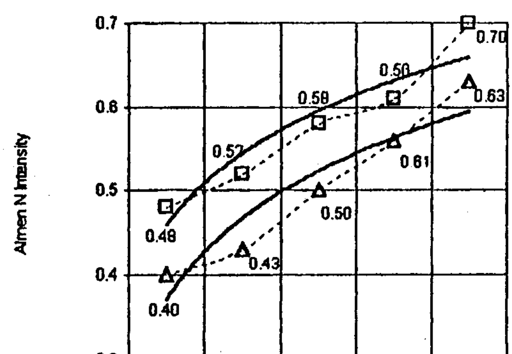


	4	5	6	7	8
Series1	110	135	160	170	190
Series2	165	170	185	190	195

Log. (Series2)
Log. (Series1)

Pressure (kgf/sq. cm)

ALMEN N INTENSITY vs PRESSURE (set 2)



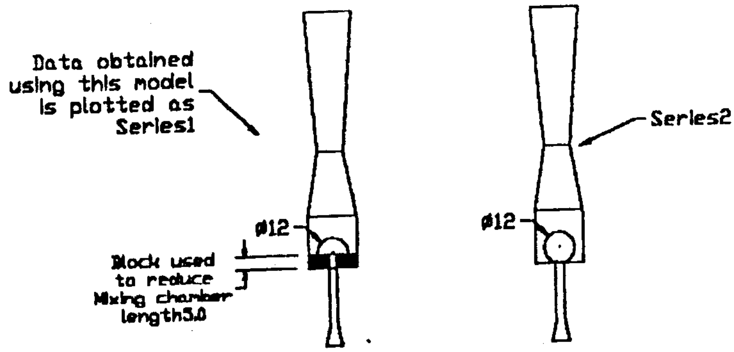
	4	5	6	7	8
Series1	0.48	0.52	0.58	0.61	0.7
Series2	0.4	0.43	0.5	0.56	0.63

Log. (Series2)
Log. (Series1)

Pressure (kgf/sq. cm)

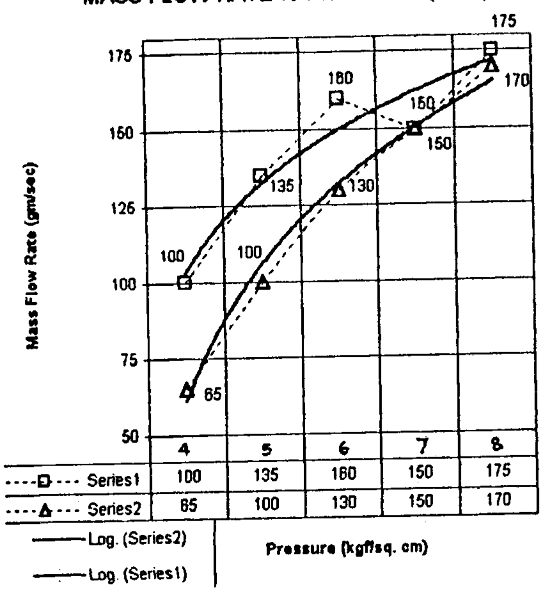
However, at higher pressure level increased shot velocity was also obtained with better coverage. At 5.5kgf/sq.cm pressure 100% coverage was obtained with an Almen A arc intensity of 0.32.

Fig.7(a), (b), (c) show the effect of secondary nozzle profiles on mass flow when primary nozzle profile was kept constant. Here again drooping has occurred as before but all these four models gave different behavior. Models gave good mass flow at higher pressure range 6kgf/sq.cm without much drooping when two suction holes were closed. For secondary nozzle it was decided to use throat diameter at least three times the ball diameter. Thus throat diameter was kept 10mm in place of 8mm, while other proportions of nozzle were kept same.



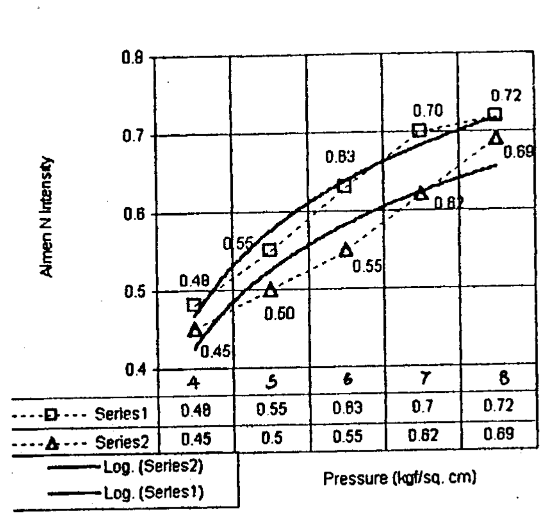
CONVERGENT DIVERGENT NOZZLE (SET-3)
Fig.7(c)

MASS FLOW RATE vs PRESSURE (set 3)



	4	5	6	7	8
Series1	100	135	160	150	175
Series2	65	100	130	150	170

ALMEN N INTENSITY vs PRESSURE (set 3)



	4	5	6	7	8
Series1	0.48	0.55	0.63	0.7	0.72
Series2	0.45	0.5	0.55	0.62	0.69

CONCLUSIONS

1. With the help of different mass flow curve and peening intensity for different secondary nozzle combinations the optimum ball peening nozzle is reported as shown in Fig.8.

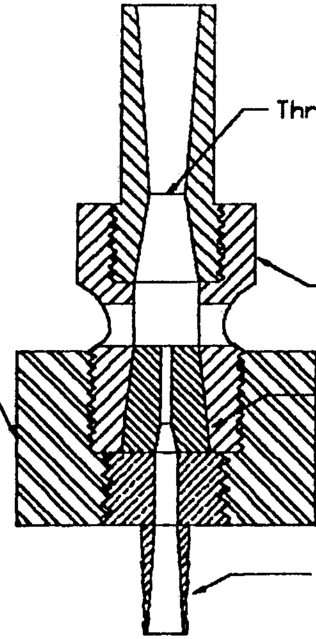


Fig.8 FINAL DESIGN OF PROPOSED BALL PEENING NOZZLE

2. Diameter of ball plays important role for some critical dimension like diameter of induction hole, length of mixing chamber, throat diameter.
3. Size of air inlet nipple joining primary nozzle to compressed air source drastically influence shot velocity and mass flow.
4. Like primary and secondary nozzle profile combination of mixing chamber size and diameter of side suction holes do influence the mass flow.
5. It was observed that with same design of mixing chamber with two suction hole, when used with both primary and secondary convergent type nozzles gave higher peening intensity compared to divergent primary and secondary nozzles. But secondary divergent nozzle gave about 20% higher coverage.

REFERENCES

1. Korzynski, M. 1990. Ball peening machines and some aspects of ball peening of steam turbine blades. Proceedings of the fourth ICSP, The Japan Society of Precision Engineering, Tokyo, Japan, pp 19-26.
2. Sharma, M. C., 'Shot Peening and Fracture Behaviour', Ph. D Thesis, Bhopal University, 1988,
3. Bhossard, R. G. Blasting Technology Engineer, Switzerland - Volsketswil.
4. Sharma, M. C., 'The Appropriate Shot Peening Technology', International Conference in Shot penning, Bhopal, 1996.
5. Nadkarni, V. S.; Sharma, M. C.; Sharma, S. G., 1990. Syphonic Peening System for glass bead peening of aluminium parts. IITT International in the proceedings of the International Conference on Titanium and Aluminium, Paris, pp 85-90.