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Study of Brass Obturator Design for Combustible Cartridge Case for 105 mm Tank Gun Ammunition

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ABSTRACT

Brass cartridge case provides rearward obturation in the tank gun ammunition where the gun system has a sliding breech mechanism. In the case of semi-combustible cartridge case (SCCC) ammunition, obturation is provided by a small metal stub. The mechanism of obturation and obturator design for kinetic energy and high explosive squash heat (HESH), SCCC ammunition of 105 mm tank gun have been studied. The dynamic firing results for SCCC ammunition for 105 mm tank gun reveal that brass obturating cup of height 115 mm provides perfect obturation. The ballistic performance of SCCC ammunition is comparable with that of the brass-cartridged round in the pressure range 150-450 MPa.

1. INTRODUCTION

Cartridge case is an important component of any gun ammunition system. Its functions are to serve as a container for the propellant, as an obturating device and as a means for assembling the components of the round for ease of loading and transportation, etc. enabling realisation of the desired ballistic parameters.

A combustible or semi-combustible cartridge case (SCCC) ammunition offers tactical and logistic advantages. Hence, combustible cartridge cases (CCCs) are fast replacing metallic cartridge cases for tank or artillery ammunition, but the CCC also presents problems in the use of conventional gun breech system, as the material of CCC gets consumed during the gunfiring cycle and there is no means to control the escape of hot gases from the breech end. For preventing rearward escape of gases, a self-sealing breech mechanism is desired in a gun. Alternatively, if the conventional gun breech system is to be retained, at the same time availing of the advantages offered by CCC, it will be desirable to have a hybrid cartridge case/partially consumable cartridge case/SCCC.

The SCCC has two components : Metallic obturator and combustible body. The metallic obturator not only retains full propellant efficiency for propelling the projectile, it also provides safety to the gun crew and the gun component by effectively sealing the rearward escape of gases. It also acts as a receptacle for the ignition system. The metal obturator is made of brass or steel. The combustible body designed and developed by the High Energy Materials Research Laboratory[1] (HEMRL), Pune, meets all the desired functional requirements.

This paper presents the design of a metal obturator for a SCCC for 105 mm tank gun ammunition. The metal obturator could be produced by two methods : (a) Cold drawing and then machining to the desired dimension, and (b) cutting the service metal cartridge case at the

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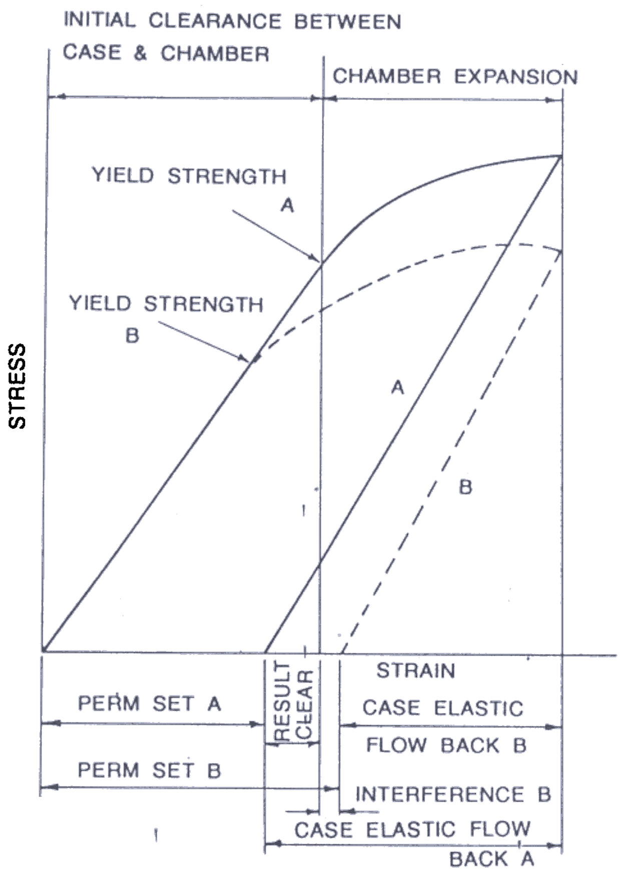

Figure 1. Case—chamber stress-strain curve

required height. The first option was ruled out for the present work as it involves heavy expenditure on designing tools and dies. Therefore, the second option was taken up, as it enables faster and easier production of the obturator. This study was carried out with brass obturators obtained from passed conventional brass cartridge cases. These cartridge cases were manufactured by the ordnance factories.

2. OBTURATION MECHANISM

Initially, the metal cartridge case is loaded in the gun chamber; generally a gap of 0.25 mm is provided between the metal cartridge case and the gun chamber wall. During the firing cycle, both cartridge case and the gun chamber expand due to high gas pressure and high temperature. Later, both of them contract due to release of this pressure.

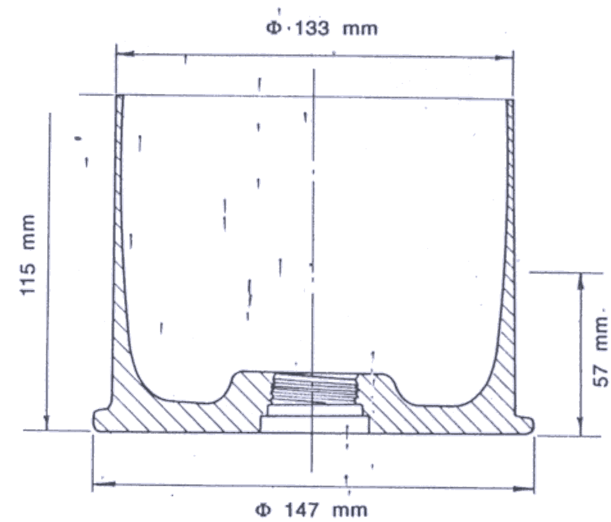

Figure 2. Brass obturator (M_1)

These situations are illustrated in Fig. 1, where case—chamber stress-strain curve is shown.

The brass (70:30) cartridge case has a yield strength of 2670 kg/cm^2 and varying degrees of hardness throughout its length. The head is relatively hard and is, therefore, able to resist deformation under the high gas pressure of the propellant gases and also to withstand the strain of primary extraction even when the cartridge case is tight in the chamber. The mouth of the brass cartridge case is soft enough to expand freely under the influence of propellant gases. There is gradual blending of one hardness to another between the hard head and the soft mouth. The degree of hardness of the metal cartridge case depends upon the type of ammunition (fixed or separate), the peak propellant gas pressure, etc.

3. DESIGN OF OBTURATING CUP

Two basic parameters influence the design of the metal obturator cup, viz., (a) attachment of CCC to metal obturator, and (b) breech end sealing.

3.1 Fixing of CCC to Metal Obturator

It is not possible to have a mechanical joint between CCC and the metal obturator. The only alternative is to fix CCC to the metal obturator with the application of an adhesive. To have good bond strength between the CCC and the brass obturator cup, a minimum of 40-45 mm lap joint is required, which can withstand the severe jolt of loading/ unloading from the gun chamber as well as from the stowage bins. On examining the inner contour of the brass cup obtained from the full brass case, it is observed that height up to 57 mm from the base has a sharp tapered portion followed by an almost straight portion with slight taper to match the outer taper of the brass cartridge case (Fig. 2). By taking all the relevant parameters for attachment of CCC into consideration, the brass cartridge case was cut at 115 mm length from the flange end, and used in this study.

3.2 Breech End Sealing

To obtain perfect obturation, the metal obturator must expand to provide proper sealing and also come to its original position for ease of extraction. Thus, the mouth of the brass obturator should have less thickness and lower hardness for ease of expansion and extraction. The base of the metal obturator should have more thickness and higher hardness to withstand high propellant gas pressure as well as pressure of extractor pull.

4. EXPERIMENTAL DETAILS

Dynamic gunfirings were carried out from 105 mm tank gun using SCCC for armoured piercing discarding sabot (APDS) and high explosive squash heat (HESH) ammunition, but having three different types of brass obturators : (i) brass obturator as such, (ii) brass obturator with packing material, and (iii) annealed brass obturator.

4.1 Brass Obturator

The first set of SCCC ammunition was prepared using a brass obturator obtained by cutting 115 mm length from the brass case and fixed with the combustible body. It was assembled with the required propellant charge mass, primer and projectile. These SCCC ammunitions were fired from carriage-mounted and tank-mounted guns. The results of dynamic gun firing are presented in Table 1.

Table 1. SCCC ammunition with brass obturator

Weapon	Ammunition	No. of rounds fired	Av. Pressure (MPa)	Av. muzzel velocity (m/s)	Remarks
C	APDS*	2	451	1471	
C	APDS*	5	464	1487	
C	HESH**	3	168	735	
C	HESH**	5	169	742	
T	APDS***	12	439	NR	Dense smoke in crew chamber. Mockup of crew broken into pieces.
T	HESH****	3	NR	750	Dense smoke in crew chamber. No impression on mockup of crew.

C Carriage-mounted gun.

T Tank-mounted gun.

* Propellant NQ/M 047 (Lot CF 21158), Charge mass 5.3 kg and 5.35 kg.

** Propellant NQ/S 156-056 (Lot CF 21779) Charge mass 2.270 kg.

*** Propellant NQ/M 047 (Lot CF 22703), Charge mass 5.1 kg. Additive liner used.

**** Propellant NQ/S 156-056 (Lot CF 21779), Charge mass 2.2 kg.

Temperature : Ambient.

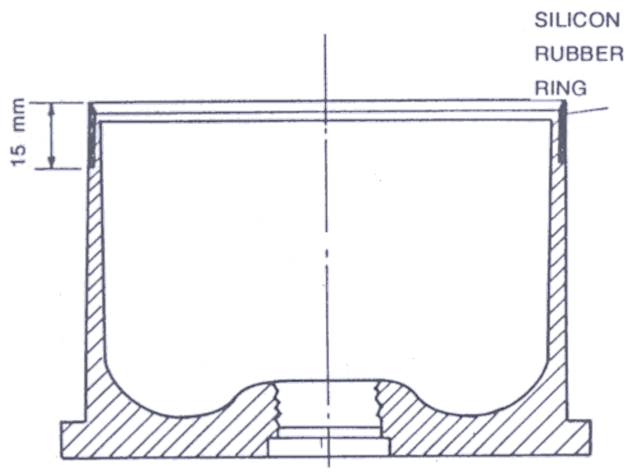

Figure 3. Brass obturator with packing material

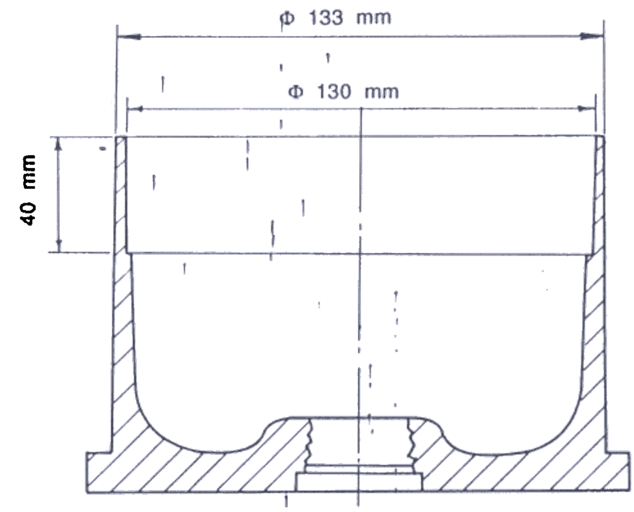

Figure 4. Annealed brass obturating cup (M_2)

4.2 Brass Obturator with Packing Material

A basic characteristic required for the packing material is that it should expand under propellant gas pressure to prevent rearward escape of gases (Fig. 3). In addition, it should not deteriorate during the firing cycle, when it comes in contact with hot propellant gases.

Based on these requirements, a polymeric material like silicon rubber with Shore 'A' hardness 50-70 was selected and fixed to the brass obturating cup. Blast measurement data and toxicity level values obtained during dynamic gun firing carried out by using these brass obturators are presented in Table 2.

4.3 Annealed Brass Obturator

To achieve uniformity of annealing, it was decided to use the brass obturator as it is, and also by thinning the lip portion up to 40 mm from the lip (Fig. 4). Thinning was carried out on standard machines, but precaution was taken to keep the tool at low rpm with plenty of coolant. Some of the processes tried for annealing were: (a) Flame annealing, (b) sand bath annealing, (c) electrolytic annealing, and (d) induction annealing.

Annealing processes (a), (b) and (c) did not serve the purpose of achieving controlled annealing for the reasons (i) zonal annealing was not possible, (ii) cooling of the annealing bath was difficult, and (iii) the brass obturator got overheated.

However, brass obturators annealed using sand bath were subjected to gunfiring trials. The results obtained are given in Table 3.

Induction heating only enables the control over zonal heating with perfect control over

Table 2. SCCC ammunition with brass obturating cup having packing material

Type of ammn.	No. of rounds fired	Type of cartg. case	Blast in crew chamber (MPa)			Toxicity level (ppm)		Remarks
			Ch.	Ch. II	Ch. III	CO	NO_2	
APDS/T (a)	10	SCCC	1.48	1.03	NR	0.1	0.4	Blackening of brass obturating cup & silicon ring separation
HESH (b)	4	SCCC	.3	0.75	NR	0.02	0.9	-----do-----

APDS/T Propellant NQ/M 047 (Lot CF 22703), Charge mass 5.3 kg. Additive liner used.

HESH Propellant NQ/S 156-056 (Lot CF 21779) Charge mass 2.2 kg.

Temperature : Ambient.

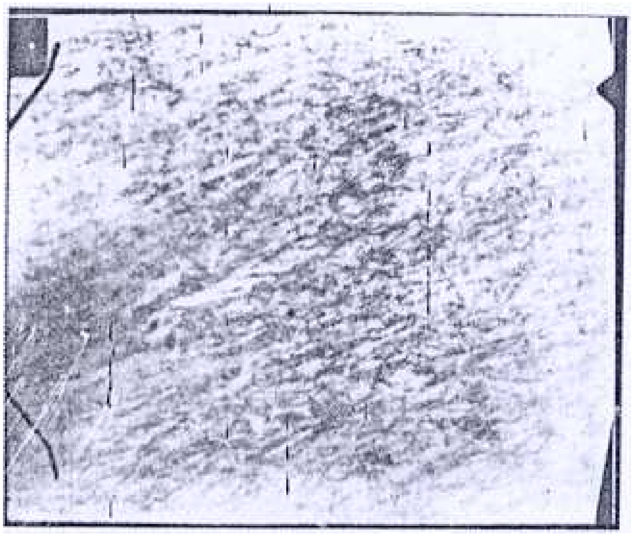

Figure 5. Micrograph taken at 75 mm distance from the lip

Figure 6. Micrograph taken at 45 mm distance from the lip

temperature. The induction heating system manufactured by M/s Pillar Corporation, Wisconsin, USA, was used in this study. Induction heaters made up of copper tubes were cooled by water. The annealed brass obturator cup samples were subjected to metallurgical testing for their hardness. The results are presented in Table 4. Microscopical studies were also carried out. Test pieces were fine-polished and etched with etching medium, which was 25 per cent aqueous solution of ammonium hydroxide with a few drops of hydrogen peroxide added (6 per cent). Microscopical studies were done at different locations to study the effect of annealing. The results obtained are presented in Figs 5-9.

Table 3. SCCC ammunition with brass obturating cup annealed in sand bath

Brass cup type	Type of ammn.	No. of rounds fired	Av. pressure (MPa)	Remarks
M1	APDS	5	448	Dense smoke at breech end
M1	HESH	5	192	----do----
M2	APDS	5	439	----do----
M2	HESH	5	190	----do----

Note All firings were carried out from the tank.

M1 Brass obturating cup as it is.

M2 Brass obturating cup (with thinned lip).

APDS Propellant NQ/M 047 (Lot CF 22703), Charge mass 5.3 kg. Additive liner used.

HESH Propellant NQ/S 156-056 (Lot CF 21779) Charge mass 2.2 kg.

Temperature : Ambient.

Annealed brass obturating cups assembled with the CCC were subjected to weapon system trials from 105 mm tank gun. The results are presented in Table 5. During the trials, the

Table 4. Hardness of brass obturating cups after induction annealing

VPN hardness at 5 kg. load	
At 10 mm from lip	At 40 mm from lip
67	158
69	180
68	157
70	168
66	157
68	161
70	168
72	175
74	171
77	158

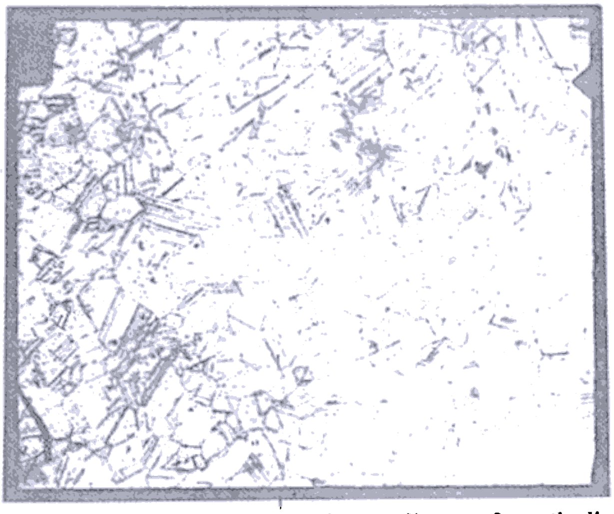

Figure 7. Micrograph taken at 25 mm distance from the lip

Figure 8. Micrograph taken at 10 mm distance from the lip

backblast as well as toxicity level were measured by using lollypop type pressure gauges inside the crew compartment at different locations (Fig. 10).

5. RESULTS & DISCUSSION

The results given in Table 1 indicate that when SCCCs attached to the brass obturator without any modification were subjected to gun firing trials from carriage-mounted gun, no significant observations could be made at the breech end. However, when firing was done from tank-mounted gun, backblast and profuse smoke emission were observed at the breech end. Based on these observations, functioning of fume extractor, breech mechanism and metal obturator were studied. In the fume extractor, cleanliness of hole and ball sitting, etc. was examined; these were found to be in working condition. In breech mechanism, the semi-automatic mechanism and the sliding wedges were checked and their functions were critically examined. There was no abnormality. Fume emission and backblast at breech end could thus be attributed to the brass obturator. Failure of obturator could be attributed to the high hardness values (170-190 Vickers pyramid number (VPN)) of the brass obturator, indicating that the yield strength of the metal obturator is too high. Thus, straining of the wall of the obturator lags behind the build-up of propellant gas pressure. Hence, failure of the obturator occurred, resulting in obturation failure at the breech end.

To overcome the problem of obturation, brass obturators were modified by providing silicon

Table 5. SCCC with brass obturating cups after induction annealing

Type of ammn.	No. of rounds fired	Type of cartg. case	Blast in crew chamber (MPa)		Toxicity level (ppm)		Remarks
			Ch.	Ch. II	CO	NO_2	
APDS	4	SCCC	0.05	0.029			No abnormality
HESH	4	SCCC	0.005	0.173	0.001	NR	-----do-----
APDS	15	SCCC	Loader*	Gunner*	NR	NR	No backblast or smoke

* Tank crew were inside the tank at their respective places.

APDS Propellant NQ/M 047 (Lot CF 22703), Charge mass 5.3 kg. Additive liner used

HESH Propellant NQ/S 156-056 (Lot CF 21779) Charge mass 2.2 kg.

Temperature : Ambient.

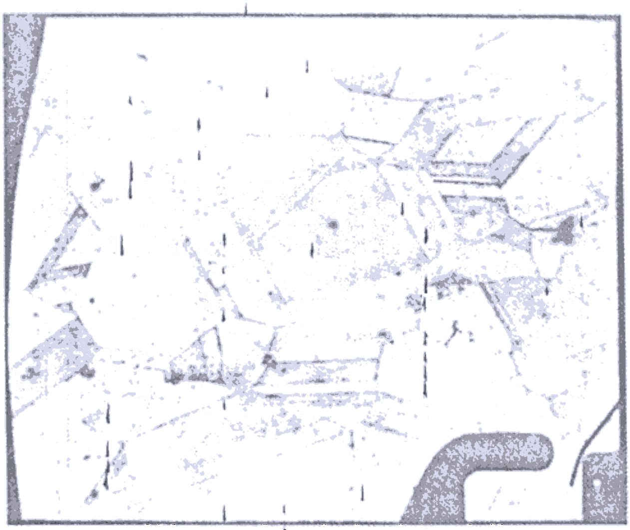

Figure 9. Micrograph taken at the lip

packing material and subjected to gunfiring trials. The results presented in Table 2 indicate that the polymeric ring either breaks or peels-off on firing and remains inside the chamber after ejection of the obturator. Due to constraints of lip thickness of the brass obturator, further work could not be carried out.

To mitigate this problem, annealing of the brass obturator was resorted to. It is difficult[2] to work out a definite time schedule and temperature that would result in a specific grain size due to two variables : Extent of cold working and the original grain size. After experimentation, annealing was carried out by heating the brass obturator in the temperature range 500-700 °C followed by natural air draught cooling.

The results presented in Table 3 give an idea of the performance of brass obturators that were annealed in sand bath. Average hardness values of 137 VPN and 185 VPN at 10 mm and 40 mm, respectively from the lip were obtained. On dynamic firing, heavy smoke was observed at the breech end in the firing pressure range 150-450 MPa.

For achieving better results, controlled annealing using the induction process was done. Initially, at the induction energy level of 18 kW, 22 Hz, 55 V for 2 min, lips of the brass obturator became red hot and burning was observed. This was attributed to high temperature which is close to the solidus and probably due to part volatilisation of zinc[3]

To circumvent this problem, the level of energy was changed to 15 kW, 18 Hz, 50 V and the time for application was also changed to 2 min 15 s. The annealed samples were allowed to cool in natural air draught. The hardness values are given in Table 4. The average hardness values in the range 65 ± 5 to 165 ± 5 VPN with 5 kg load were more or less achieved at 10 mm and 40 mm, respectively from the lip, whereas unannealed brass obturating cups after cutting from the brass

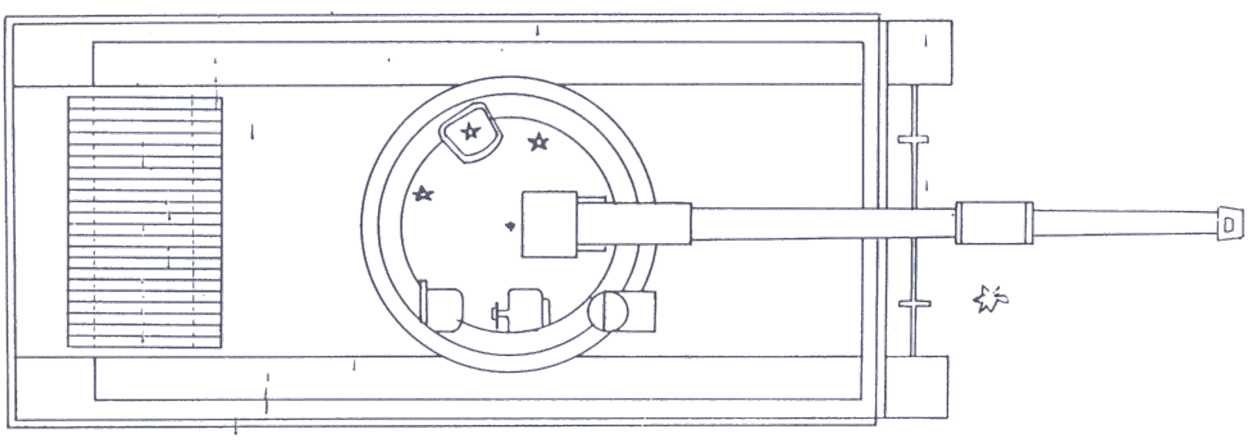

Figure 10. Layout of gauges in the crew compartment

cartridge cases showed hardness values of 195 ± 5 VPN at 5 kg load throughout their length.

The effect of induction heating was further investigated by studying the microscopical crystal structures and crystal growth[4]. The micrograph taken at 75 mm from the lip of the brass obturator shown in Fig. 5 indicates intensive cold working with profound strain bands and grains elongated into fibres. The effect of heat during annealing has not penetrated this zone.

The micrograph in Fig. 6 indicates that new crystals are formed in strain areas; these undergo slight growth by the time less deformed areas have recrystallised. Coring is also observed at certain places.

Brass (70:30) obturating cups are made by the cold drawing process followed by annealing. This results in recrystallisation; subsequently, crystal growth takes place and the internal stress and hardness are reduced.

The micrographs in Figs 7-9 reveal the above phenomena as well as marked growth of crystals. Brass being face-centred cubic metal, annealing twins are observed which are characterised by flat trimming surfaces in the micrographs. The marked crystal growth in these micrographs indicates that the temperature towards the lip rises gradually to the higher side, as a result of which the crystals grow in size by fusing. Thus, microscopical studies clearly indicate the desired effect of annealing on cold drawn brass obturator.

To assess the effectiveness of obturation with these annealed brass obturating cups, these were subjected to gunfiring trials at Proving Ranges. The results presented in Table 3 give a clear indication that these brass obturators when properly annealed gave perfect obturation and withstood the breech gas pressure without smoke emission or backblast.

6. CONCLUSIONS

1. Brass obturating cup of length 115 mm, 65 ± 5 VPN hardness at the lip of the brass cup and 160-200 VPN hardness at 40 mm from the lip of the brass cup gives perfect obturation and permits easy extraction in the pressure range 150-450 MPa.

2. Induction heating is best suited for annealing brass obturating cups.

3. The ballistic performance of 105 mm tank gun ammunition with SCCC is comparable to that obtained with brass case.

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REFERENCES

1. Syal, R.K.; Sindker, D.V.; Talegaonkar, S.B.; Saudi, S.K.; Borole, K.D.; Narr, P.S.; Khire, S.M. & Shah, V.M. High Energy Materials Research Laboratory, Pune. Combustible cartridge case formulation for tank/artillery gun ammunition and its method of manufacture. Indian Patent filed. 17 January 1995.

2. West, E.G. Copper and its alloys. Elis Hardwood Ltd., UK, 1982.

3. ICI Limited. Cassel manual of heat treatment and case hardening. Imperial Chemical Industries, Ed.7. 1974.

4. Richard, H.G. & Harod, W. Practical microscopical metallography. Chapman and Hall Ltd., London, 1951.

Contributors

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