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6.0 MANUFACTURE:

A) Raw material (Ingot/Bloom):

- i) The steel shall be melted in basic oxygen furnace or electric arc furnace followed by secondary refining.
- ii) The molten metal shall be degassed through vacuum degassing arrangements to ensure freedom from harmful inclusions & gaseous content. The hydrogen content in the liquid steel shall be 2ppm max.

Note: The manufacturer shall give a certificate to the effect that the initial bloom/ bar stock has been made from ingot having at least four times cross- sectional area. Also source of manufacture of bloom / bar stock must be mentioned in the certificate.

B) Quality of ingot/bloom:

- i) Steel used for ingots shall be fully killed and homogeneous. Ingots shall be adequately cropped so as to be free from pipe, segregation and other harmful defects.
- ii) In the ingots, the internal defects of steel, as evaluated by macro etching test as per IS:11371-85 shall not be worse than S-2, R-2 & C-2 as per ASTM E-381.
- iii) The discard from top and bottom of the ingot must not be less than 15% of the weight of balance of ingot. The correct grain size as called for in, clause 14 of this specification, after forging and heat treatment.
- iv) The forgings shall not be manufactured from continuously cast blooms / billets / bars.

Note for conditioning of blooms: During processing, the blooms shall be conditioned to remove injurious surface defects, provided the depth of conditioning does not exceed 1mm for every 15mm of concerned dimension, up to a maximum depth of 20mm and provided that the width of the conditioning is at least four times its greatest depth. The maximum depth of conditioning on two parallel sides at opposite locations shall not exceeds one & half times the maximum allowed for one side. The transition between conditional & non conditional areas shall be gradual. All heavy swarf and/or slag shall be removed. After removal of surface defects from the blooms, magnetic particle testing & ultrasonic examination may be carried out on all the blooms to ensure freedom from surface defects & internal defects respectively.

C) Reduction ratio:

- i) The minimum reduction ratio from the minimum section of the ingot to maximum section of the round bloom / billet / bar shall be 4:1 and the reduction ratio in height by upset forging from round bloom /billet / bar to blank stage for gear wheel & pinion blanks shall be minimum 4:1.

Note: Details of product, details of manufacture including method of forging & forging ratios (in compliance of clause 6.(vii) of this specification) with stage wise sketches, dimensions and forging reduction ratios of the intermediate stages, stage wise inspection plans shall be submitted by the supplier at the time of his offer and shall achieve the same in actual gear/pinion blank forgings. The dimensions and forging reduction ratios, along with photographs of the intermediate & final stages of the actual forgings, shall be submitted along with each consignment. BHEL can witness the manufacturing process compliance as per the requirements of drawing & specification at any stage of manufacturing at supplier's works.

D) Method of forging:

- i) The pinion blanks shall be forged by the method of upset forging.
- ii) The gear wheel forgings shall be made by close die forging by process of upset forging, followed by peripheral forging under a power hammer or press. The forging and rolling process shall be performed in such a manner that the central axis of the bloom coincides with the axis of the gear wheel.



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7.0 FREEDOM FROM DEFECTS:

The forgings shall be free from defects, such as cracks, fold, flakes, seams, segregations, nonmetallic inclusions and other injurious defects which may affect the utility of the forging. The internal material shall be homogeneous.

No welding is permitted on the forged gear & pinion blanks.

8.0 CHEMICAL COMPOSITION:

8.1 The melt analysis of the steel and permissible variation in the composition of the forgings from the melt analysis shall be as per IS:4432 -1988 (reaffirmed 2004 or latest) Gr. 15Ni7Cr4Mo2 & are reproduced below:-

Element	Composition		*Permissible deviation in melt analysis	
	% Min	% Max.		
Carbon	0.12	0.18	±	0.02
Silicon**	0.15	0.35	±	0.03
Manganese	0.60	1.00	±	0.04
Nickel	1.50	2.00	±	0.05
Chromium	0.75	1.25	±	0.05
Molybdenum	0.10	0.20	±	0.03
Sulphur	-	0.035	±	0.005
Phosphorus	-	0.035	±	0.005

NOTE:

* + or - means that in one cast, the deviation may occur over the upper value OR under the lower value specified in the cast analysis but not both at the same time.

** When the steel is silicon killed, the minimum silicon killed content shall not be less than 0.15% and the negative permissible deviation shall not be applicable.

8.2 Elements not specified in the above table shall not be added to the steel except where agreed to, other than for the purpose of finishing the heat and shall not exceed the following limits:

<u>ELEMENT</u>	<u>Max %.</u>
Copper	0.25
Vanadium	0.05


9.0 HEAT TREATMENT:

Forgings shall be homogenised at 900 - 930 ° C.

Forgings shall be normalised at 860 to 880 ° C and air-cooled.

Tempered / sub-critical annealed at 650 to 700 ° C.

Test pieces shall also be heat-treated as mentioned above along with forgings they represent.

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10.0 TEST SAMPLES:

10.1 Samples with Consignment:

i) 4 nos. separately forged longitudinal test samples (18±1 mm dia and 610 mm long) per heat & heat treatment batch (for each batch size of max. 50 nos. gear blanks/400 nos. pinion blanks or part thereof), shall be provided for testing at BHEL along with the forgings. The supplied test samples to be machined from duly forged test bar, having similar reduction ratio, heat and heat treatment as the forging it represents.

ii) In case forgings of same heat & heat treatment batch are supplied in different consignment, the test samples shall be supplied along with 1st consignment.

Notes: 1) The supplier should ensure that the test samples supplied shall be of same heat as the gear/pinion blank forgings they represent and heat treated along with the forgings as per clause 9.0 of this specification. The supplied test samples shall be duly stamped with supplier's name, heat no., heat treatment batch no. & PO no.

2) Refer clause no. 14.2.3 for the requirement of test sample with consignment for macro-etch test.

3) Supplier to furnish the capacity of heat treatment furnace in the format annexed as annexure-III of this specification.

10.2 Samples with Consignment (During purchasing of fully finished gears & pinions):

i) 4 nos. separately forged longitudinal test samples (18±1 mm dia and 610 mm long) per heat & heat treatment batch (for each batch size of max. 50 nos. gears/400 nos. pinions or part thereof), shall be provided for testing at BHEL along with the forgings. The supplied test samples to be machined from duly forged test bar, having similar reduction ratio, heat and heat treatment as the forging it represents.

ii) In case gear/pinion of same heat & heat treatment batch are supplied in different consignment, the test samples shall be supplied along with 1st consignment.

iii) Three spy test pieces, (25 mm dia and 25 mm tk) per batch of 50 nos. gears/100 nos. pinions or part thereof, in the heat treated (carburized & hardened) condition same as the fully finished gears/pinions they represent, shall be provided per heat & heat treatment batch for testing at BHEL.

Notes: 1) The supplier should ensure that the test samples (as given in point (i) & (iii) above) supplied shall be of same heat as the gears/pinions they represent and heat treated as per the requirements mentioned in points (i) & (iii). The supplied test samples shall be duly stamped with supplier's name, heat no., heat treatment batch no. & PO no.

2) Refer clause no. 14.2.3 for the requirement of test sample with consignment for macro-etch test.

11.0 HARDNESS AS RECEIVED:

The forgings when tested in accordance with IS: 1500 shall show a hardness value of 170 - 220 HB.



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12.0 RESPONSE TO HEAT TREATMENT:

18mm dia. bar machined to 16mm bar for tensile testing and 18mm square for Charpy impact test. After machining the following heat treatment shall be followed:-

Samples after heating to carburizing temperature and single quench heat treatment, as detailed below shall show the mechanical properties given in clause 13 of this specification.

Blank Carburising : 880-930° C (For sample sizes up to 25mm, 1-1½ hrs)
(Heating to carburizing temperature in the absence of carburizing atmosphere)

Single Quench Temperature : 820-840° C (For sample sizes up to 25mm, 1-1½hrs)

Quenching Agent : Oil (IOCL make Servo Quench-11) (At normal room temperature)

Tempering temperature : 180 - 200° C (For sample sizes up to 25mm, 1-1½ hrs)

Note: In the test samples submitted by the supplier for testing at BHEL as per clause 10.0 (in the condition as mentioned in clause 9.0), the heat treatment as per clause 12.0 will be done in BHEL.

13.0 MECHANICAL PROPERTIES:

Test pieces after heat treatment as detailed in Clause 12 of this specification, shall show the properties given below:

13.1 Tensile:

When tested to IS: 1608, test pieces shall show the following values:

- i) Tensile strength : 1100 - 1400 N/mm²
- ii) Yield Stress : 750 N/mm² min.
- iii) Elongation on 5.65 √So gauge length : 9%, min.
- iv) Reduction in area : 40%, min.


13.2 Charpy Impact Value (ISO-V):

When tested in accordance with IS:1757, the test pieces shall show an average Charpy impact value of 22 Joules, minimum over 3 test values while the lowest value of the 3 values being not less than two third the average value obtained. However, all the three values shall be reported.

14.0 METALLOGRAPHIC EXAMINATION:

14.1 For Bar Stock:

One bar stock shall be cut in the presence of Inspecting Agency and macro tests shall be done on the same to ensure that sufficient working has been done on the ingot to obtain the bar stock.

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14.2 For Forged Blank:

14.2.1 Microstructure:

The microstructure shall be uniform without any carbon segregation. Banded structure upto 50 microns width is permissible.

The austenitic grain size, when tested in accordance with ASTM E 112 shall be in the range of 5 to 8 or finer at 100 X.

14.2.2. Macroetch Test (On actual rough machined forged blank):

The Macroetch examination shall be done as per ASTM E 381 (Method of Macroetch Testing and Inspection of steel Forgings). The macroetched sections (cross-section of the gear/pinion blank forgings from ID to OD as per respective drawing) shall reveal satisfactory flow line pattern right up to the centre of the forged blank.

The shape of the forging should be as per rough machined drawing of gear/pinion blank forgings keeping only machining allowance of maximum 15 mm on each tool point so that the grain flow is retained in final machined gear/pinion blank forgings.

The supplier should furnish dimensional sketch of the gear/pinion blank forging section showing grain flow pattern in compliance of above requirements along with offer against each enquiry and shall achieve the same in actual gear/pinion blank forgings. The required grain flow pattern shall be revealed during macro-etch test.

14.2.3 Test sample with consignment (For macro-etch test):

Provision of gear/pinion blank forging (1 no. in addition to the ordered quantity) to BHEL by new or regular vendor for macroetch test along with its cost shall be in the scope of the supplier. This is applicable for both the vendors supplying rough machined gear/pinion blanks or fully finished gears/pinions.

NOTE: 1) For New Vendors:

The new supplier may carry out its internal macro-etch test on actual rough machined gear/pinion blank forging to ensure the grain flow pattern as per the requirement of the specification. One extra gear/pinion blank forging for macroetch test shall be supplied to BHEL along with first consignment for random selection & testing at BHEL.


2) For Regular Vendors:

i) In the case of supply of any gear/pinion blank as per different drawing (which involves manufacturing of different die) by the regular supplier for the first time, one extra gear/pinion blank for macroetch test at BHEL end shall be supplied along with first consignment.

ii) Macroetch test on actual gear/pinion blank forgings shall be repeated at an interval of every three years of last macroetch test of supplier's supply of that particular gear/pinion blank forging or earlier at BHEL discretion whenever the failure of gears and pinions of particular forging supplier takes place. For above, one extra gear/pinion blank for macroetch test at BHEL end shall be supplied along with first consignment for random selection & testing at BHEL.

14.3 Inclusion Rating:

Inclusion rating of the steel shall be determined in accordance with ASTM E 45. The worst field of each inclusion from the specimen shall be recorded as a rating for the specification. The inclusion rating shall not exceed 2.0A, 2.0B, 2.0C and 2.0 D (Both thin and heavy series) as ASTM E 45.

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15.0 ULTRASONIC TEST:
Rough machined pinion and gear blank forgings shall be ultrasonically tested in accordance with BHEL standard AA0850118, Ultrasonic Testing - Classification and Acceptance Standard for Steel Forgings, Billets and Bloom, and shall comply with Category - 2 of the acceptance standards specified therein.

16.0 TEST CERTIFICATE:

16.1 Raw Material used for Forging:
The test certificate from the steel mill for the raw material procured by the supplier, detailing the melt method/process route, heat no., chemical composition, hydrogen content & reduction ratio (in case of bloom) shall be supplied.

16.2 Forgings:
Three copies including original copy of a test certificates (on testing agency/supplier letter head with seal, signature & date) shall be supplied, unless otherwise stated in the order, in the Test Certificate proforma annexed to this specification (Annexure -I).
In addition, the supplier shall ensure to enclose one copy of the test certificate along with their dispatch documents to facilitate quick clearance of the material.
The following details shall be furnished in the test certificate:

- i) Dimensional inspection.
- ii) Details of heat treatment.
- iii) Chemical composition including trace elements.
- iv) Results of mechanical tests. Details of heat treatment cycle as per clause 12 adopted on test bar for mechanical tests to be submitted in addition to Annexure-I.
- v) Results of metallurgical tests including banding of microstructure.
- vi) Results of ultrasonic examination.
- vii) Results of additional tests called for in the drawing/order.

17.0 OTHER TECHNICAL REQUIREMENTS:
For other technical requirements, refer annexure-II of this specification.

18.0 PACKING & MARKING:
Forgings shall be suitably packed to prevent damage during transit.
Each forged blank shall be stamped with: TM10581 / Melt / Heat No.
Each package shall bear the following information:
TM10581 - 1.75% Nickel Chromium Molybdenum Steel Forgings - For case Hardening.
BHEL Order No.
Suppliers Name
Consignment/ Identification No.
Weight

19.0 REFERRED STANDARDS (Latest publications Including Amendments):

1) IS: 1500	2) IS: 1608	3) IS:1757	4) IS:4432	5) BS:970, part 1
6) ASTM E 45	7) ASTM E 112	8) ASTM E 381	9) AA 0850118	



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ANNEXURE-I: RECOMMENDED TEST CERTIFICATE FORMAT FOR FORGINGS

SUPPLIER'S NAME & ADDRESS														
TEST CERTIFICATE FOR FORGINGS														
1. Customer:				9. Reduction Ratio				Ingot to Bloom Bloom to Blank						
2. TC No. & Date:				10. Heat / Melt No.:										
3. PO No.:				11. Heat treatment batch No.:										
4. Process of Melting Ingot:				12. Spec. No.:										
5. Deoxidisation Process:				13. Test Bar Size & Nos.										
6. Forging Method (Open/closed die):				14. Supplier of the ingot/ billet/ Bloom & TC reference										
7. BHEL's Reference for Approval of Bloom				15.										
8. Discard: Top % ; Bottom %														
15. FORGINGS COVERED BY TEST CERTIFICATE														
Heat No.		Heat treatment batch no.				Quantity				Sl. no. of gear/pinion blanks				
16. GAS CONTENT (PPM)						17. CHEMICAL COMPOSITION (PERCENT)								
Gas		H ₂	O ₂	N ₂	C	Si	Mn	S	P	Cr	Mo	Ni	Other trace elements like Al, Cu	Radioactive Contamination
As Per Specn.		Min.												
		Max.												
Actual Values														
18. HEAT TREATMENT (To be accompanied by Recorder Chart)														
Condition		Heating Rate, °C/hr.		Temp., °C		Soaking Time, Hrs.		Cooling Rate, °C/hr.		Cooling Medium				
19. MECHANICAL PROPERTIES														
		T.S N/mm ²	Y.S 0.5/0.2% Proof N/mm ²	% Elongation 5.65 %So GL	% R.A Min.	Hardnes s BHN (Min 3 Values)	Impact Value Joules	Bend Test						
								Angle of bend	Dia. of mandrel	Result				
As Per Specn.		Min.												
		Max.												
Actual Values														
20. SURFACE FINISH (when called for in the order/drg.)														
21. DIMENSIONAL INSPECTION														
22. NON-DESTRUCTIVE TESTS														
Nature of Test		Acceptance level		Instrument used		Range		Result		Any other detail				
Ultrasonic														
Radiographic														
Dye Penetrant/ Magnetic Particle														
23. METALLOGRAPHIC EXAMINATION (To be conducted if called for and photo micrographs to be attached along with a report)														
Location of Sample		Etchant used		Magnification		Constituent observed		Relative %						
Microstructure		Macroetch		Inclusion Rating		Banding of microstructure								
24. OTHER TESTS IF ANY (MICROSCOPIC, SULPHUR PRINTS, ETC)														
25. IDENTIFICATION OF FORGINGS AS PER PURCHASE SPEC.														
We hereby certify that the items mentioned above have been tested and inspected in our presence and are found to be in accordance with drawings, specifications and purchase order.														
SIGNATURE, NAME & SEAL OF THE INSPECTING OFFICER DATE:							SIGNATURE, NAME & SEAL OF THE CHIEF OF QUALITY CONTROL/ CHIEF METALLURGIST OF THE SUPPLIER DATE:							
INSTRUCTIONS														
a) Details of all heat treatment processes carried out should be furnished sequentially in 17.														
b) Test certificates are to be furnished as per Purchase order and specification, in A4 size preferably in transparent paper.														
c) All the entries including signature should be in black colour ink.														
d) If testing is done by outside agencies, the original TCs shall be furnished.														
e) The actual TC may run into more than one A4 size paper, if needed, to facilitate filling up of details.														

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1.3.5 Non Destructive Testing Facilities:

Suitable UT and MPI equipment with all accessories, calibration blocks etc. shall be available with vendor to carry out all the tests mentioned in drawing & this specification.

2. Raw material (Details shall be given in relevant annexures- III, IV & V as per requirement mentioned in clauses 2.5.A) & 2.5.B):

- 2.1 Raw material source should be mentioned in the quotation of the supplier against each enquiry.
- 2.2 Along with each consignment, the supplier has to submit copy of original invoice of procurement of raw material for forgings, giving information about ingot size & quantity procured (If required, commercial details may be hidden).
- 2.3 The supplier should furnish documents in support of establishing the quantity of steel procured is in correlation with no. of blank forgings ordered to the supplier.
- 2.4 Raw material (ingot/bloom) for forgings may be from the reference list of raw material sources given below or from other sources as selected by forging supplier.

2.5 A) In case of procurement of raw material from below mentioned reference list (Details shall be given in annexures- III & IV):

In case of procurement of raw material for forgings from below mentioned reference list, forging supplier to furnish information as mentioned in above clauses 2.1, 2.2 & 2.3.

B) In case of procurement of raw material from other sources (Details shall be given in annexures- III, IV & V):

In case of procurement of raw material from other sources, forging supplier to furnish following information in addition to above clauses 2.1, 2.2 & 2.3:-

i) Declaration of steel making facilities (available with raw material supplier):

- ❖ The forging suppliers should ensure that the raw material sources as identified by them, should have all the facilities of steel making process & meeting the quality requirement as per clause 6.0 paragraph -1, 2, 3 & 4 of this specification.
- ❖ Forging supplier to furnish the declaration of availability of above mentioned steel making facilities, in the format given in annexure-V along with the techno-commercial offer submitted against enquiry.

Note: The forging supplier should ensure that the information regarding steel making facilities available with raw material supplier, is meeting the requirements of specification.

2.6 Reference list of Raw material sources for case hardening steel:

Reference list of raw material sources for case hardening steel (required for manufacturing of forgings to this specification) includes SAIL (Alloy Steels Plant, Durgapur), Mahindra Ugine Steel Company Ltd. (MUSCO), SAIL (VISL), Kalyani Carpenter Steels Ltd., Star Wire (India) Ltd., Arcvac Steels, Sunflag Iron & Steel Co. Ltd, ISMT Ltd, Mishra Dhatu Nigam Ltd. (MIDHANI), Central Foundry & Forge Plant (BHEL, Haridwar), Saurabh Metals Pvt. Ltd. (Bhopal).

Note: The above reference list of raw material sources is for guidance only. The forging supplier shall ensure the quality of raw material from the source selected by it (from the reference list/other source). The responsibility for quality of gear/pinion blank forgings & its raw material lies with the forging supplier.

- 2.7 The forging supplier should ensure the delivery of gear/pinion blank forgings as per PO requirement. Any delay in procurement of raw material/delay in supply of raw material by raw material supplier, shall not be considered as reason for delay in delivery of gear/pinion blank forgings as per PO requirement.

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**Annexure-III****Checklist for Supplier for Submission of Documents with offer**

The documents to be submitted by the suppliers along with their offer against each enquiry are as mentioned below. Duly filled checklist as per annexure-III is also to be submitted by the suppliers along with their offer.

Sl. No.	Documents to be submitted along with offer	Submitted (Yes/No)
1.	Name of raw material source selected by the supplier (as per clause 2.1 of annexure-II).	
2.	In case of selection of raw material source other than mentioned in clause 2.0 of annexure-II, submission of declaration of steel making facilities as per annexure-V.	
3.	Details of manufacture including method of forging & forging ratios (in compliance of clause 6.(vii) of this specification) with stage wise dimensional sketches (as per clause 6.0 note(ii) of this specification).	
4.	Forging supplier's stage wise inspection plans (as per clause 6.0 note(ii) of this specification).	
5.	Dimensional sketch of gear/pinion blank forging section showing grain flow pattern in compliance of clause 14.2.2 of this specification.	
6.	Confirmation for supply of one additional gear/pinion blank for macroetch test (as per the requirement of clause 14.2.2 of this specification).	
7.	Yes <input type="checkbox"/> No <input type="checkbox"/> date in which one additional has been supplied by the supplier for macro-etch test at BHEL.	
8.	Supplier to furnish capacity of heat treatment furnace w.r.t quantity of enquired gear/pinion blank forgings that can be heat treated in single batch.	

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Annexure-IV

Checklist for Supplier for Submission of Documents with each consignment

The documents to be submitted by the suppliers with each consignment are as mentioned below. Also, duly filled checklist as per annexure-IV is to be submitted by the suppliers along with each consignment.

Sl. No.	Documents to be submitted	Submitted (Yes/No)
1.	Three copies of test certificates including original copy as per the requirements mentioned in clause 16.0 of this specification. Test certificates in original shall be on testing agency/supplier letter head with seal, signature & date.	
2.	Heat treatment chart (showing heat treatment cycle adopted for forgings) from graphical recorder of furnace with heat no. & batch number. The chart shall be duly signed with supplier's seal, signature & date.	
3.	Details of heat treatment cycle as per clause 12 adopted on test bar for mechanical tests.	
4.	Coloured photograph showing microstructure & grain size of the forgings.	
5.	Dimensions, reduction ratio calculation sheet and photographs of the intermediate & final stages of the actual forgings (as per clause 6.0 note(ii) of this specification).	
6.	Copy of original invoice of procurement of raw material for forgings, giving information about ingot size & establishing the quantity of steel procured is in correlation with no. of blank forgings ordered to the supplier (as per clause 2.2 of annexure-II).	
7.	In case new/regular vendor has carried out internal macroetch test, the coloured photograph of the macroetched section shall also accompany the consignment for reference.	
8.	Ultrasonic test report (in original) duly signed & stamped by Level-II inspector.	

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Annexure-V

**At Forging supplier's /Raw material
manufacturer's letter head**

**Declaration regarding Steel making facilities available (to be furnished by
Gear/Pinion blank forging supplier)**

Forging supplier name:	
Raw material supplier name:	
BHEL PO ref. no. & date:	
BHEL PO Quantity of gear/pinion blank forgings:	
Raw material quantity ordered by forging supplier:	

Sl. No.	Facility available at raw material supplier (Steel maker)	Available/ Not available	Make & model	Capacity/ range	Year of establishment
1.	a) Basic oxygen furnace or				
	b) Electric arc furnace				
2.	Secondary refining furnace				
3.	Vacuum degassing unit				

Declared by: (Raw material supplier authorized representative name, signature, seal & date)	Verified by: (Forging supplier authorized representative name, signature, seal & date)
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- Notes:** 1) The forging supplier should ensure that the information furnished above is correct. The forging supplier shall verify the steel making facilities as claimed by raw material supplier, in compliance of specification requirements.
- 2) If at any stage it is found that the information furnished by the forging supplier regarding steel making facilities of raw material supplier is wrong, suitable action will be taken against forging supplier & its supplies as deemed fit by BHEL.