HOT WORKING TOOL STEELS WITH EXTRA FINE STRUCTURE (EFS)

Material Specification	:	ASTM A 681 H 11 and H 13
Comparable grades in other standards	:	AISI H 11 and H 13 DIN X38CrMoV51 (1.2343) and X40CrMoV 51 (1.2344) JIS G 4404 SKD 6 and SKD 6 1 BS 4659 BH 11 and BH 13
Applications	:	Die casting dies, Extrusion dies for Aluminium, Wear resisting tools

Chemical composition :

Typical values

Grade	C	Si	Mn	S	P	Cr	Mo	V
H 11	0.38	1.00	0.38	0.005	0.025	5.10	1.15	0.46
H 13	0.40	1.00	0.39	0.005	0.022	5.00	1.20	0.83

Requirements of Hot Working Tool Steels

The steel for making of hot working tools need to have some well defined characteristics to make them suitable for the purpose to which they are intended.

i. The steel should have good machinability since the tools have to be machined to intricate shapes.

ii. During service the tool is subjected to complex multi directional stresses and hence the properties should not be direction dependent. This requirement of isotropy is best met by ensuring that the steel has an uniform and extra fine structure (EFS) free of micro segregation and banding.

iii. The Sulphur content of the steel has a marked influence on the hot toughness of the steel. Increased Sulphur content adversely affects the hot toughness and the resistance to thermal shock because of the formation of undesirable Manganese Sulphide streaks in the direction of working. Because of the streaks, the properties in the transverse direction are affected adversely and hence the formation of streaks needs to be avoided. To meet the above requirements, at Goradia, strict controls on the processes are exercised at all stages of steel melting, forging / rolling, heat treatment and machining.

Procedures adopted at Goradia to meet application requirements in Hot Working Tools Steels

i. Very strict control over the input materials is exercised with regard to composition and cleaniiness to ensure that the Carbon level is maintained at the lower range of the specifications. This helps to ensure good machinability for the steel.

ii. By specially developed processing techniques during melting, Sulphur content is kept at 0.005% which ensures that the formation of Sulphides streaks during hot processing is avoided. Also the low Sulphur levels ensure that the toughness values (impact strength) in both longitudinal and transverse directions are almost similar i.e. degree of isotropy is enhanced.

iii. By proper dephosphorisation methods, the Phosphorous level is controlled below 0.025%. This increases the impact values by avoiding the formation of injurious phosphides in the matrix.

iv. Taking advantage of basic metallurgical thermodynamic principles, we have developed process for degassing the melt to control Hydrogen levels to less than 2 ppm. Because of the low gas levels, low residual Sulphur and Phophorous, the cleanliness of the steel improves considerably. The inclusion levels typically achieved are 1.0 Thin / 0.5 Heavy as per ASTME45

v. The ingots are subjected to a controlled reheating temperature cycle which helps to get "micro **segregation free"** finished product. Also strict control is exercised on the Forging temperatures by continuously monitoring the job temperature with the help of the radiation pyrometer installed on line with the forging press.

vi. For achieving the extra fine annealed structure, we have developed special heat treatment processes. Indigenously developed heat treatment cycles ensure steel with **EXTRA FINE STRUCTGURE WITH UNIFORMLY DISTRIBUTED SPHEROIDISED CARBIDES IN A FERRITE MATRIX FREE OF ANY MICRO SEGREGATION, CARBIDE NET WORK AND BANDING. The annealed micro structure conforms to GA5, GB4, GC2, GD2 GE1 or better as per VDEh charts for evaluation of annealed microstructures of hot work tool steels.** The as annealed hardness shall be 235 BHN max and the variation in hardness from surface to core does not exceed 10 BHN.

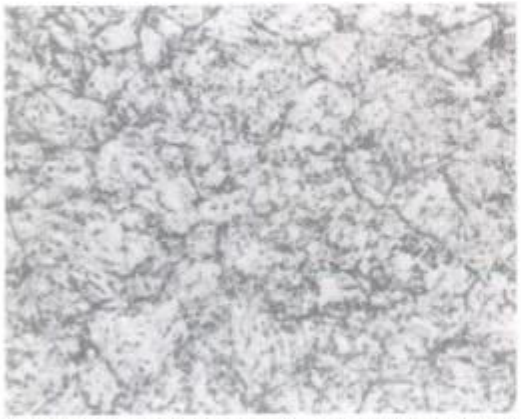
vii. A minimum reduction ratio of 4:1 from the ingot is provided during forging which ensures that the ingot structure is completely broken down. As a result of this, when tested as per ASTM E 381 standards, the macro structure conforms to C1, S1, R1 of the above standards. Also the grain size obtained when tested as per ASTM E 112 is 6 orfiner.

viii. Internal soundness of the steel bars is checked and confirmed by ultrasonic test methods. The testing is done as per ASTM A388 Standards with acceptance level as 4mm FBH. The above procedures and acceptance levels corresponds to C/c of SEP 1921 standards.

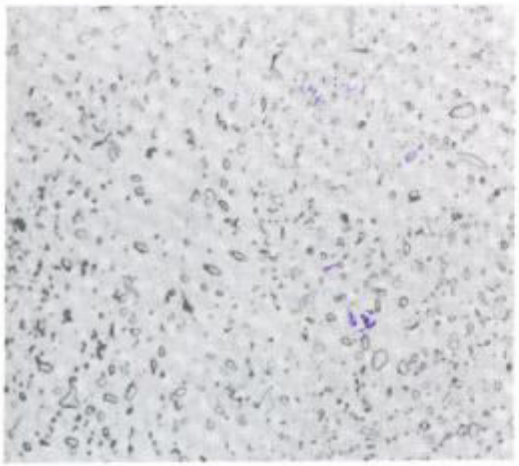
ix. Sufficient allowance for machining is provided during forging so that when proof machining is done, any decarburized layer gets removed and the job supplied is free of any surface decarburization which can affect the response to subsequent hardening process.

x. To assure freedom from mix up during processing, 100% ultrasonic testing and 100% spark testing with mobile spectrometer are conducted before the material is released for packing and dispatch.

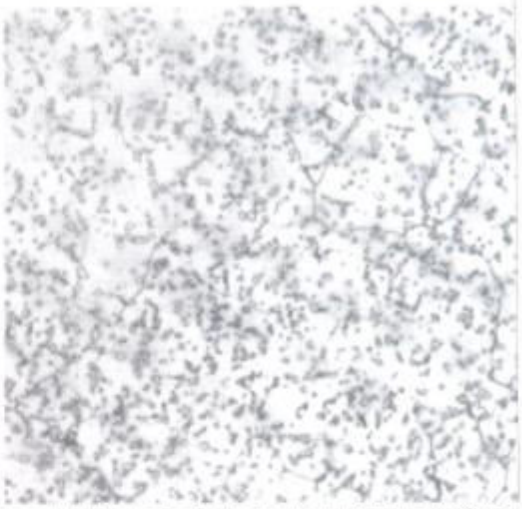
xi. The steel bars are supplied in rough turned / proof machined condition with a size tolerance of +2/-0 mm on diameter and is standard lengths of 2.5 to 5.5



Quenched and tempered structure of H 13 showing finely dispersed spherodial carbides in ferrite matrix (Magn 1000x)



Spheroidise annealed structure of H 13 showing finely dispersed spherodial carbides at 1000x magn



Annealed H11showing finely dispersed spherodial carbides in ferrite matrix at 1000x magn

with maximum 20% short length up to 1 meter length.

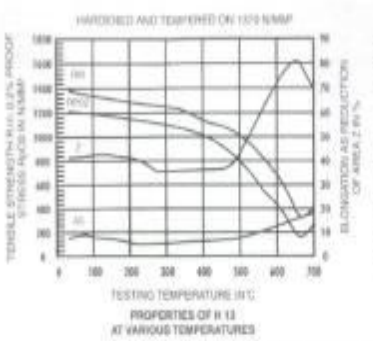
Properties of the hot work tools steels

i. Response to hardening and tempering treatment

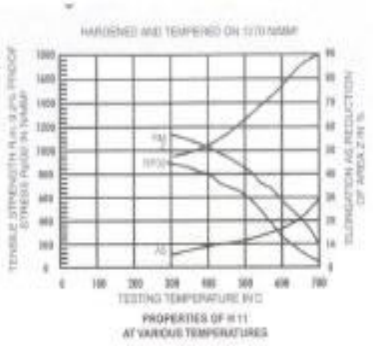
The specially developed melt processing and heat treatment techniques during production of the H11 and H13 grade steels results in a homogeneous structure without any sulphide streaks after hot working. The microstructure is of the extra fine type without any carbide net work. The EFS helps in uniform dissolution of the carbides during subsequent hardening treatment. Therefore the resulting structure after hardening is also equally uniform. Further because of the special heating treatment process used, the structure is free of any banding and segregation. This enhances the performance of the tool in service greatly.

ii. Strength and toughness at elevated temperatures

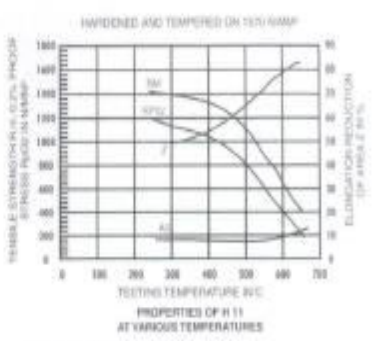
As their name implies, hot work tool steels are used at high temperatures. Their ability to retain their strength and toughness at their working temperatures are consequentially



PROPERTIES OF H 13
AT VARIOUS TEMPERATURES



PROPERTIES OF H 11
AT VARIOUS TEMPERATURES



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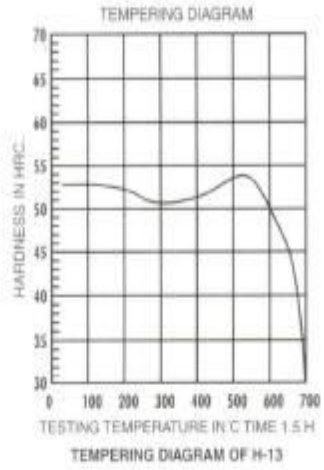
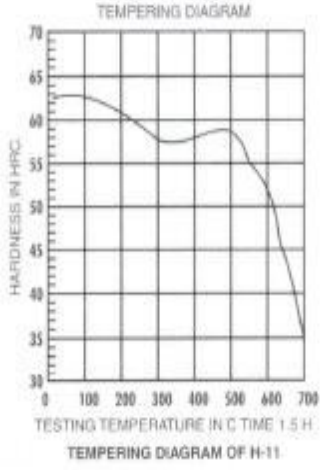


TEMPERING DIAGRAM OF H-13



TEMPERING DIAGRAM OF H-11

of greater importance than the room temperature properties. Extensive studies on elevated temperature properties of hot working tool steel reveal a marked increase in impact strength at elevated temperatures without substantial loss of strength. This makes the steel ideally suitable for high temperature tool applications.

Productivity.

Summary

The extra fine structure and uniform micro structure obtained by the special processing techniques adopted ensure that the hot working tool steel to manufactured is ideally suited to meet the highly critical properties demanded by the service conditions.