OVERHEATING

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INTRODUCTION

- The term "overheating" has been loosely used in the past to indicate the structure associated with austenitic grain growth, for instance the precipitation of ferrite in a Widmanstatten pattern. In view of the temporary nature of the effects of this phenomenon it is desirable to differentiate it from overheating as described below, the effects of which are persistent.
- Inferior mechanical properties of a steel resulting from coarse austenite grains can be improved by hot working and grain refining treatments. The effects of overheating and burning, on the other hand, are difficult to remove. Burning may damage the steel beyond resuscitation; it may also impair the forging properties of the steel.

- **SYMPTOM**
- When a steel is heated above a certain temperature, generally known as the overheating temperature, changes which take place at the austenitic grain boundaries reduce the resistance of these regions to fracture. After the steel is reheated, quenched and tempered so that the resistance to fracture of the matrix is increased, the steel will break, during notched impact test, along the previous grain boundaries giving rise to a fracture containing a number of mat crystal facets in a fibrous structure. These facets correspond to the previous grain interfaces.
- The optimum heat-treatment required to develop the facets in an overheated steel depends on the composition of the steel. In general, oil quenching from the austenite range followed by tempering at 600° C for 1 hour is most suitable for alloy steels. No systematic investigation has been published for plain carbon steels; tempering at 200°C has been reported as suitable for a mild steel.

- The size and the number of facets in a fracture increase with increasing temperature

- **Effects :-**
- The ductility and impact toughness of a steel are reduced by overheating, but the tensile strength is not affected except when it is severely overheated. That fatigue strength of a steel is lowered. Premature failure in aeroengine components, such as connecting rods, has been attributed to overheating during forging.
- The austenitizing temperature above which the symptom of overheating appear after suitable heat treatment is known as the overheating temperature. It varies from steel to steel, even from one heat to another for a steel of the same specification, but it normally lies above 1200° C. There are indications that the overheating temperature decreases when the carbon content of the steel is increased.
- The overheating temperature of a steel is lower and hence the susceptibility to overheating is higher, the fewer the inclusions. Probably for this reason, electric steels generally have a lower overheating temperature than open hearth steels. The overheating temperature can be raised by drastic quenching or very slow cooling from the high temperature, and by the use of less sensitive tests. For instance, the overheating temperature determined by nitro sulphuric acid etch is slightly higher than that by ammonium nitrate etch or fracture test.

- Therefore it can be determined only for a set of fixed conditions, including the technique of etching and repolishing. The only effective methods of reclaiming the steel known at present are :-

1. Reheating the steel to the original heating temperature, followed by cooling at a rate not greater than 3°C. per minute through the overheating range.
2. Repeatedly austenitizing the steel at successively lower temperatures at 100-150°C intervals. The properties of an overheated **steel can be improved by repeatedly normalizing, but no** full recovery is possible without the above treatment.

CAUSES

- The appearance of overheated structures occurs when numerous fine manganese sulphide inclusions are observed on the grain interface (Fig. 10), which can be exposed by suitable techniques.
- These inclusions are too thin to be seen in a normally polished metallographic specimen.
- Ko and Hanson concluded that the solubility of sulphur in austenite in the presence of manganese increases with increasing temperature. When a steel has been heated to high temperatures, sulphide inclusions are dissolved during heating, and subsequently, during cooling to below the overheating temperature, reprecipitated
- (i) on residual sulphide inclusions,
- (ii) on austenite grain interfaces, and
- (iii) sometimes on (100) crystallographic planes of austenite.
- The presence of inclusions at the grain boundaries of small curvature weakens the resistance to fracture of these planes and, when the matrix is toughened by suitable heat treatment, the fracture will propagate along these planes of sulphide precipitation

BURNING

- The term "burning" is misleading as it implies the effect of combustion in air or oxygen.
- In fact, burning, similar to overheating, is independent of the furnace atmosphere,
- **SYMPTOM**
- The burning of a steel is indicated by the presence of a light etching network outlining the austenite grain boundaries, (Fig. 12), when the steel is etched with alcoholic solution of nitric acid, and of a dark-etching network when picric acid is used.
- The structure in a burnt steel, revealed by etching with nitrosulphuric acid and ammonium nitrate are the reverse of those obtained in the overheated steel, (Fig. 13 and 14). Strings of sulphide inclusions can often be seen along the grain boundaries (Fig. 15), which are covered with a two dimensional network of iron manganese sulphide.
- The sulphide was precipitated as one component of a eutectic during cooling after burning, (Fig. 16), the other component being iron. Burning can occur at a temperature well below the solidus of an alloy- of the same chemical composition but free front sulphur.

- **EFFECTS:-**
- The presence of a liquid at the high temperature, as evidenced by the presence of eutectic after cooling, reduces the ductility, and tensile strength, and in severe cases the steel may disintegrate during forging giving fractures of distinctly intergranular appearance.
- But the liquid at the grain interface is not necessarily present as a continuous film covering the whole interface. The eutectic at the grain interface in a severely burnt steel is often observed in colonies and hot tensile tests made by Winterton of British Welding Research Association on a eutectoid carbon steel (Steel T mentioned in Ko and Hanson's paper) well above the solidus showed that, unlike commercially pure aluminium, considerable ductility remained at these temperatures :

Testing Temperature °C	Tensile Strength Tons per sq. in	Elongation on in.	Reduction in Area
955	4·7	77	99
1302	1·7	76	100
1351	1·2	100	100
1388	1·0	77	88
1397	0·9	24	58

Causes.

Investigation made with pure materials showed that burning is chiefly associated with the formation of a sulphur-rich liquid at the grain interface at high temperatures. When phosphorus is present as is usually the case in steels, it congregates in the liquid, and, after cooling, gives rise to an iron net-work rich in phosphorus, revealed by the various etching reagents as a network.

Burning is normally observed at unexpectedly low temperatures, which had led various investigators to suggest that burning could not he caused by incipient fusion. Ko and Hanson showed that in sulphur-free iron carbon alloys burning does not occur below the solidus, and they suggested that the solidus of the steel has been exceeded when burning takes place, the solidus being lowered by the sulphur dissolved in the austcnitc.