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# AN ATTEMPT TO INVESTIGATE THE TOUGHNESS ENHANCED HEAT TREATMENT PROCESS FOR LEAF SPRING

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## Abstract

An investigation has been made for finding the heat treatment process for remarkable enhancement in toughness property of leaf springs. At leaf spring of Bed Ford trucks, being fabricated by All-Win company in Karachi, was selected for manufacture of present work. Before and after the annealing hardening, tempering and austempering heat treatment processes, the hardness, toughness and micro-structures were examined by using Brinell and Rockwell hardness testers, Charpy impact testing machine and optical microscopes.

The results of present work shows that austempering is only toughness enhancing process, which not only shows the remarkable improvement in toughness values but also maintain high hardness without the loss in ductility and consequences of distortion and quench cracks.

## Introduction

The heat treatment process is one of the metallurgist tools by means of which, quality, efficiency and reliability of engineering structures is enhanced without altering its design parameters and chemical constituents, so as to achieve structural integrity conveniently.

Depending upon the material and desired mechanical properties, many heat treatments have been developed so for. Among these aneaning, normalizing, hardening, tempering and austempering are the traditional heat treatment processes which are most commonly and extensively used in almost all engineering structure forming industries so as to facilities the commencing fabrication process and to impart he specified mechanical properties as and when desired.

Since the mechanical, physical and chemical properties of engineering structures are specified by the service, conditions. Like wise maximum toughness with considerable hardness value, adequate ductility high fatigue strength and better weldability are the specified properties of leaf spring in order top withstand under the repeated loading conditions and to absorb the millions and trillions of shocks of different altitudes so as to make the soft and comfort riding.

This needs appropriate selection of chemical composition, engineering design, fabrication process and heat treatments. The catastrophic failures of leaf spring in present era-enforce to review the mechanical and metallurgical aspects so as to achieve the goal of high structures integrity.

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The present work is just initiation in this regard to review the engineering heat treatment processes and to search out the suitable substituter if possible conveniently by means of which. The quality, efficiency and reliability of engineering structures could achieve.

**Material**

A leaf of leaf spring was purchased from the shop of autoparts for the present study. The material analysis made from Ship Yard engineering works Karachi reports that the material used for manufacturing of lead spring is AISI 5160 whose chemical composition is reported in table.1

**Experimental Methods**

1. Specimens for a hardness testing, toughness testing and metallography were prepared as shown in fig.1 from as received leaf of leaf spring. The thickness of all types of specimens is considered same, so that equal soaking time can be maintained. During cutting of specimens the oil as a lubricant was used for subsequent lubrication just to avoid the distortion of micro-structure due to heating.

2. Before subjecting the specimens to heat treatment processes the hardness and toughness values were measured by using Brinell and Rockwell hardness testers and charpy impact testing machine respectively. Besides this the microstructure of as received material was examined (Fig.2) by optical microscope. The results are shown in Table-2.

3. After tabulating the initial results all specimens for hardness, impact and metallography were annealed, hardened, tempered and austinitized. The general characteristics of each process exercised during present work is as under.

**Annealing Characteristics**

| | |
|---|---|
| Critical Temperature | 85° C |
| Soaking Time | 5 Min. |
| Quenching Media | Furnace Cool |

After 24 hours the annealed specimen were tested. The results are shown in table 3 and fig. 3

**Hardening Characteristics**

| | |
|---|---|
| Critical Temperature | 85°C |
| Soaking Time | I Min/mm thickness |
| Quenching Media | Oil |

The tests were conducted whose results are shown in Table 4 and fig.4

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**Tempering Characteristics**

Just after hardening process the specimens were tempered at 450°C, 500°C and 550°C for one hour in the oil media. The results are shown in Table 5 and fig 5

**Tempering Characteristics**

| | |
|---|---|
| Critical Temperature | 850°C |
| Sub-Critical Temperature | 340°C |
| Nature of Salt | 55% KN 03+45% $NaNO_3$ |
| Soaking Time | 1 Hour |
| Quenching Media | Oil |

The results of austempered specimen are shown in table 6 and fig. 6.

**Results and Discussion**

The results of annealing, hardening, tempering and austempering are shown in table 3,4,5, & 6 and Fig. 5,6,7 & 8.

It is very clear that enhancement in toughness value is none in annealing than the austempering and hardening followed bu tempering. But it is not fit for leaf spring due to the loss in hardness which is so severe side effect that one can not compromise with it. On the other hand hardening and tempering tough improves the hardness value but decrease the toughness.

In fact the hardness and roughness properties of material are inversely related with each other 2,3,4 that is why one improves at the compensate of other. Due to this reason neither annealing for hardening or tempering shows +ve effect on both properties. Austempering on the other hand seems to be suitable heat treatment process which not only shows the remarkable enhancement in the toughness value but also improves hardness value. This is because of the fact that austermpering process is neither merely thermal process for isothermal is purely the isothermal process which gives too soft microstructure (i.e. pearlite), while the hardening is a thermal process which give birth to hard microstructure (i.e. martensite). Though the tempering to had microstructure (i.e. sorbite) but fails to provide highly tough micro structure. However in the austermpering process both thermal and thermal principles works simultaneously due to which neither austenite decompose into soft microstructure nor hard, but in between hard and soft. The by-product of austenite due to austempering is bainite, which shows good balance and compromise between toughness and hardness than any other micro structure. Almost zero probability to quench cracks or distortion is an additional attraction for attempering. The intermediate cooling rates are the basic reasons behind this fact. Thus the chance of strained microstructure during austempering approaches to zero.

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## Conclusion

It is concluded from present work that austempering is only toughness enhancing process while retaining the high value of hardness. In the light of the present work the authors recommend the austempering process of leaf spring than the hardening followed by tempering as being practice by Allwin Company.

## References

1. Mr. Abro, Mr. Memon, Mr. Abbasi "Failure Analysis of Leafspring "S.U.R. JOURNAL" Vol. 29 (1), 83-88, (1997)
2. F.B. Pickering, "Proceedings of International Sumposium on high Strength low Alloy Steel " Oct. 1975.
3. M.J. Robberts, "Effects of Transformation Substructures on the Strength and Toughness of Fe-Mn Alloys" Met Trans, Vol. 1970, P-3291
4. V.F. Zackay, E.R. Parker, D. Fahr and R.Bush, "The Enhancement of Ductility in High Strength Steels" Trans ASM Vol.61, 1969, P-843
5. S.D. Auto Lovich and B.Singh, "On the Roughness Increasement Associated with the Austenite Phase Transformation in TRIP Steels" Met Trans, Vol.2, 1971, P-2135.
6. Avener, "Physical Metallurgy".
7. Hony Comn. "Steels Microstructure and Mechanical Properties".

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**TABLE : 1**

**CHEMICAL COMPOSITION IN WT%**

| S.NO. | ELEMENT | %AGE OF WEIGHT |
|---|---|---|
| 01. | Carbon | 0.5 to 0.5 |
| 02. | Manganese | 0.65 to 0.95 |
| 03. | Silicon | 0.15 to 0.35 |
| 04. | Chromium | 0.6 to 0.95 |
| 05. | Phosphorus | 0.035 |
| 06. | Sulfur | 0.033 |

**TABLE : 2**

**MECHANICAL PROPERTIES OF AS RECEIVE SPECIMEN**

| | |
|---|---|
| Brinell Hardness No. | 387.6 BHN |
| Rockwell Hardness No. | 40 HRC |
| Toughness | 1.2 kg mm |
| Microstructure | Sorbite |

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**TABLE : 3**

**MECHANICAL PROPERTIES AFTER ANNEALING**

| Sr. No. | Brinell Hardness | Rock Wall Hardness | Toughness | Microstructure |
|---|---|---|---|---|
| 01. | 125.97 | 13.5 | 03 | Pearlite |
| 02. | 125.0 | 13.1 | 3.2 | Pearlite |
| 03. | 125.5 | 13.2 | 3.0 | Pearlite |

**TABLE : 4**

**MECHANICAL PROPERTIES AFTER HARDENING**

| Sr. No. | Brinell Hardness | Rock Wall Hardness | Toughness | Microstructure |
|---|---|---|---|---|
| 01. | 532.95 | 55 | 1.0 | Martensite |
| 02. | 532.5 | 54.6 | 1.0 | Martensite |
| 03. | 533.5 | 55.9 | 1.0 | Martensite |

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**TABLE : 5**

**MECHANICAL PROPERTIES AFTER TEMPERING**

| Sr. No. | Tempering Temperature | Brinell Hardness | Rock Wall Hardness | Toughness | Microstructure |
|---|---|---|---|---|---|
| 01. | 450 | 406.98 | 42 | 1.2 | Martensite |
| 02. | 450 | 406.5 | 42 | 1.2 | Martensite |
| 03. | 450 | 405.0 | 41 | 1.2 | Martensite |
| 01. | 500°C | 357.6 | 40 | 1.29 | Laminated Sorbite |
| 02. | 500°C | 357.4 | 40 | 1.29 | Laminated Sorbite |
| 03. | 500°C | 357.0 | 39.5 | 1.29 | Laminated Sorbite |
| 01. | 500°C | 375.97 | 38.0 | 1.35 | Sorbite |
| 02. | 500°C | 375.6 | 38.7 | 1.36 | Sorbite |
| 03. | 500°C | 375.00 | 38.2 | 1.39 | Sorbite |

**TABLE : 6**

**MECHANICAL PROPERTIES AFTER AUSTEMPERING**

| Sr. No. | Brinell Hardness No. | Rockwell Hardness No. | Toughness | Microstructure |
|---|---|---|---|---|
| 01. | 465.12 BHN | 49.5 HRC | 1.95 kg/mm | Bainite |
| 02. | 463.99 BHN | 48.5 HRC | 1.95 kg/mm | Bainite |
| 03. | 464.52 BHN | 47.5 HRC | 1.95 kg/mm | Bainite |
| Mean Results 464.54 BHN | | 48.3 HRC | 1.83 kg/mm | |

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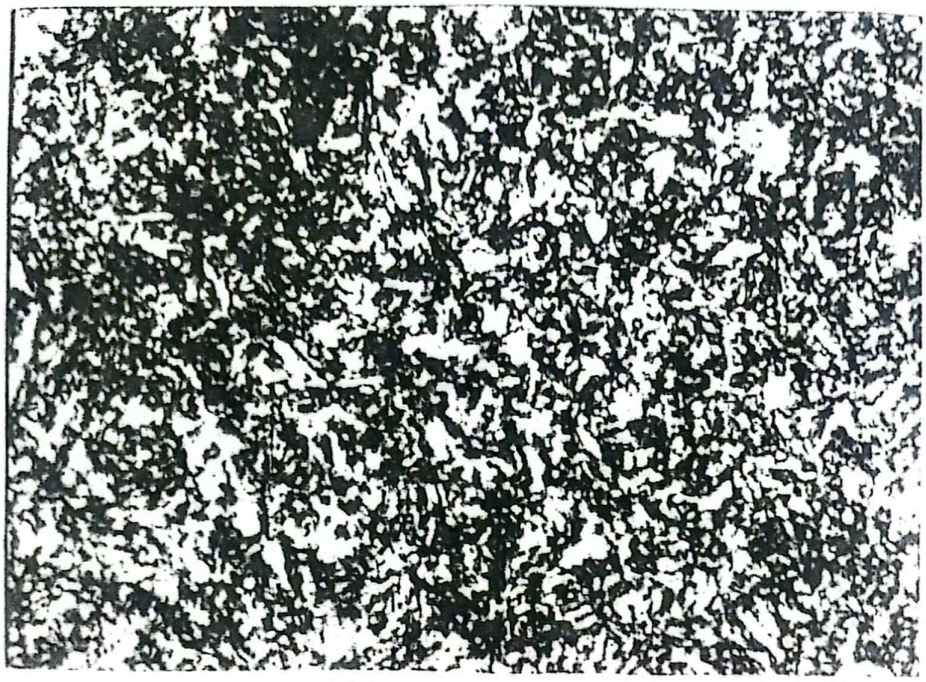


FIG:2 SORBIT MICROSTRUCTURE OBSERVED AT 400 MAG:

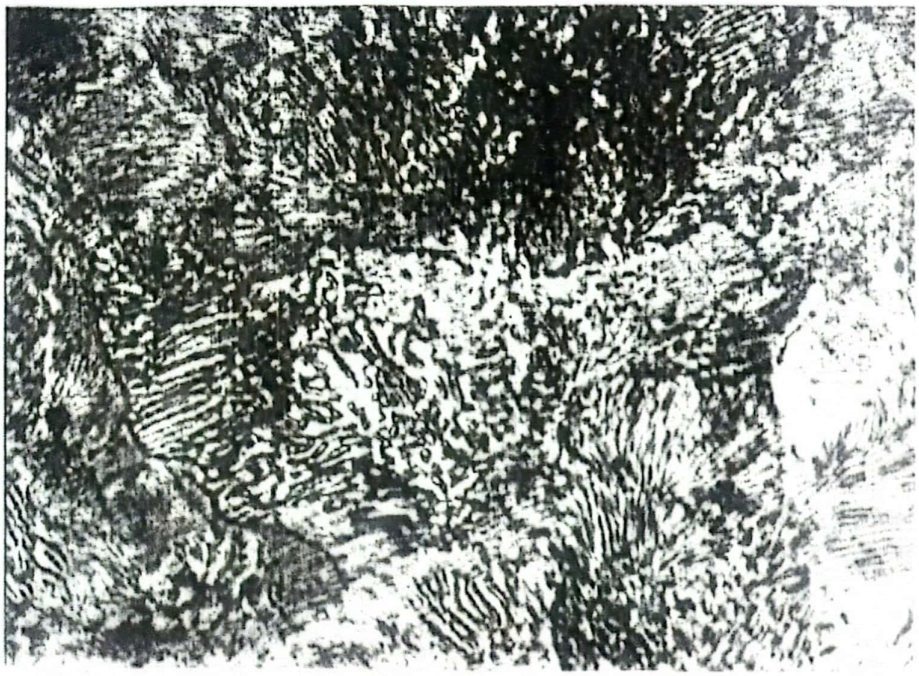


FIG:3 PEARLITE MICROSTRUCTURE OBSERVED AFTER ANNEALING AT 400 MAG.

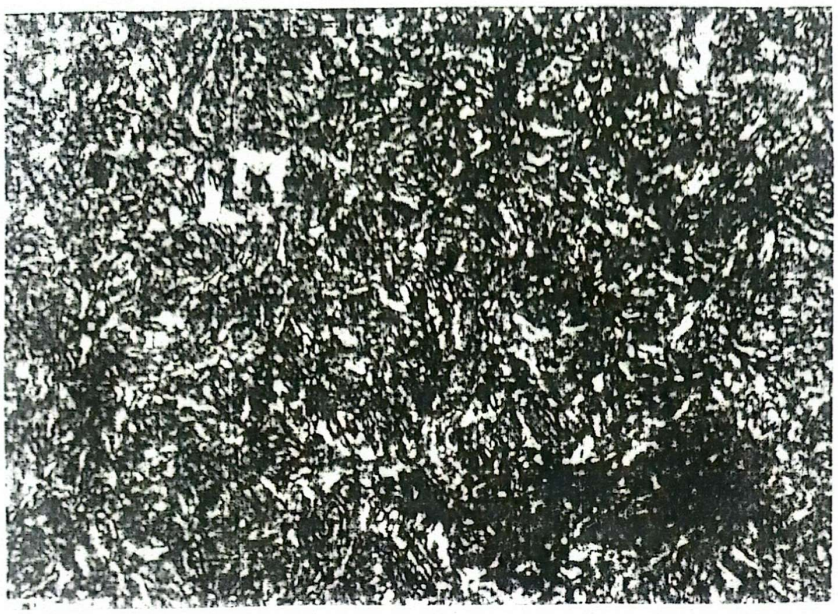


FIG:4 MARTENSITE STRUCTURE OBSRERVED AFTER HARDENING AT 400 MAG.

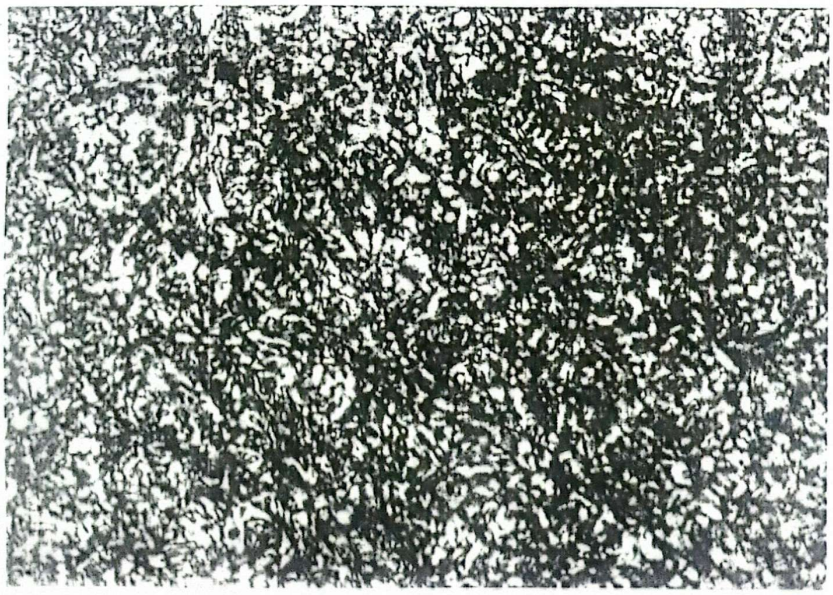


FIG:5 MARTENSITE MICROSTRUCTURE OBSERVED AFTER TEMPERING AT 450 C AT 400 MAG.

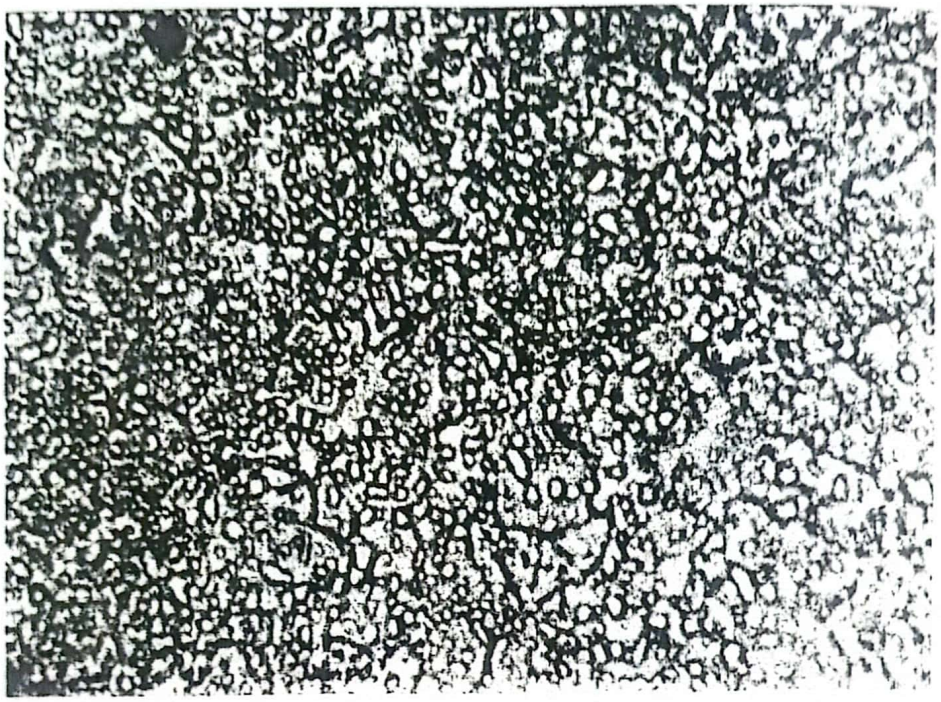


FIG:5b LAMINATED SORBITE MICROSTRUCTURE OBSERVED AFTER TEMPERING AT 500 C AT 400 MAG.

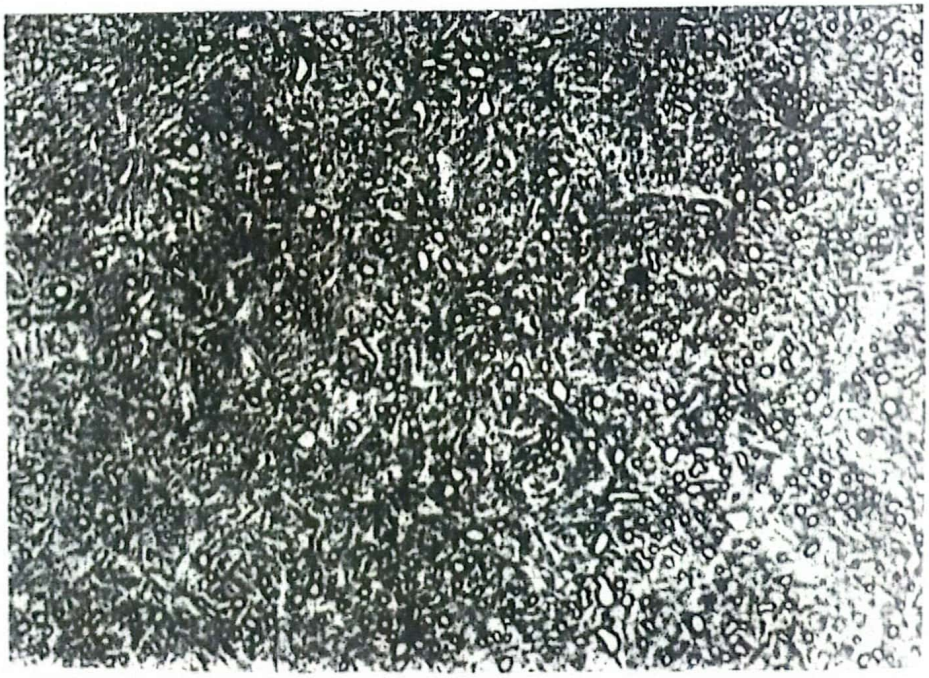
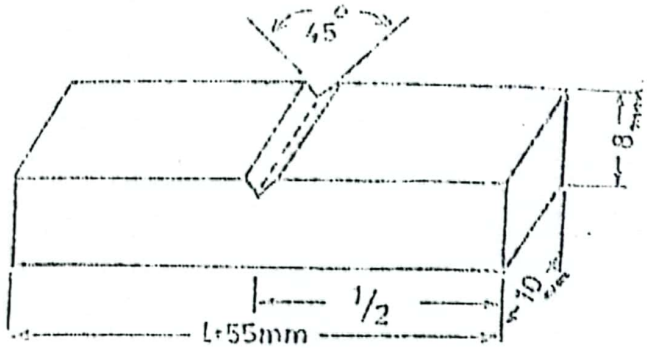
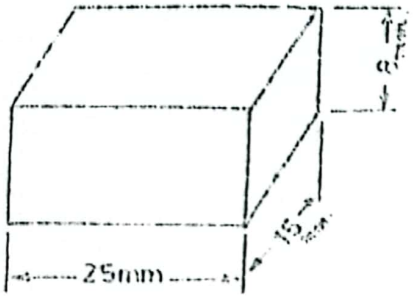


FIG:5c SORBITE MICROSTRUCTURE OBSERVED AFTER TEMPERING AT 550 C AT 400 MAG.



FIG:4 LOWER BAINITE MICROSTRUCTURE OBSERVED AFTER AUS-TEMPERING AT 349 °C AT 400 MAG.



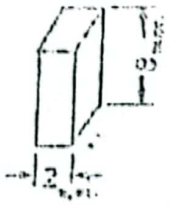



Fig
(a) TOOGHNESS SPECIMEN.
(b) HARDNESS SPECIMEN.
(c) METALLOGROPHY. SPECIMEN.