Application of a Double-Grooved Spring Steel 55SiMnVB in the Aeolus Truck EQ-140

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ABSTRACT

ALL trucks produced in the Second Automobile Works(SAW), with annual capacity of 100,000 trucks, have adopted leaf springs with double-grooves incorporated on the compression side. A Silicon-Manganese-Vanadium-Boron grade steel (55SiMnVB) was developed with very low tendency of decarburization in heating and very good hardenability on quenching. With rational cross-sectional configuration, a reduction in weight of 10.5% of spring assembly is realized.

SAW adopts unique induction heating of spring leaves. The exceedingly short time of heating further excludes the possibility of decarburization. Another unique technology is individual cooling of spring leaves. After tempering, spring leaves undergo pre-stressing shot-peening. The final process is electrostatic coating with infrared drying.

China possesses the highest mountain ranges in the world with some very severe road conditions, the successful operation of over 500,000 AEOLUS trucks has well proved the success of this spring material and its processing technology.

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A NEW ORIGINAL STEEL GRADE 55SiMnVB developed in China exhibits the following good mechanical properties: high tensile strength, high ratio between yield and tensile strengths, long fatigue life, high tenacity and good plasticity. It has also other good characteristics such as low tendency of surface decarburization, which is a fatal factor in fatigue, good quenching and temper resistance properties.

Effective measures have been taken by SAW and DA YE Steel Works in research, design and manufacture of this type of steel and spring leaves, with good results such as low weight and long service life of the final spring assemblies.

PROPERTIES OF THE STEEL 55SiMnVB

The research of steel grade 55SiMnVB dated back to the R & D stage of a development new type of Chinese truck in 1966. The steel was purposely developed for making leaf suspension springs of that.

Compared with the traditional choice

of leaf spring steel such as the Chinese $60Si_2Mn$ and Japanese SUP_6, the content of silicon in 55SiMnVB is reduced from 1.5% - 2.0% to 0.7% - 1.0% the result of which is a reduction of both sensitivity of decarburization and inclination to graphitization; while the content of carbon is cut down from 0.56% - 0.64% to 0.52% - 0.60%, which results a little further reduction of tendency of decarburization. (Fig.1)

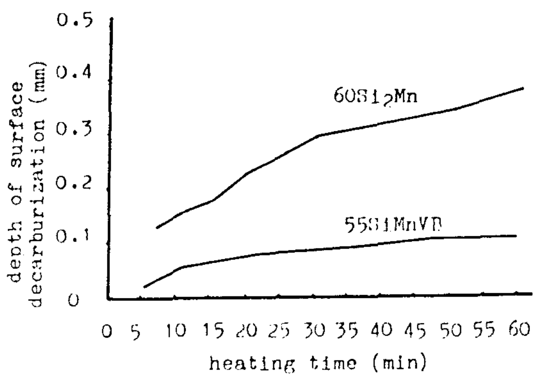

Fig.1 Comparision curves of decarburization of steel 55SiMnVB and $60Si_2Mn$ at 900°C

By adding 0.08% - 0.16% vanadium, the crystal grains of the steel are refined. This improves strength and toughness of the steel.(Table 1) The addition of 0.001% - 0.0035% boron ensures deep quenching depth(1). (Fig.2)

Table 1 Comparision of mechanical properties between $60Si_2Mn$ and 55SiMnVB after heat treatment

steel grade	σ_s (MPa)	σ_b (MPa)	δ_{10}%	ψ%
55SiMnVB	1225	1372	5	30
$60Si_2Mn$	1176	1274	5	25

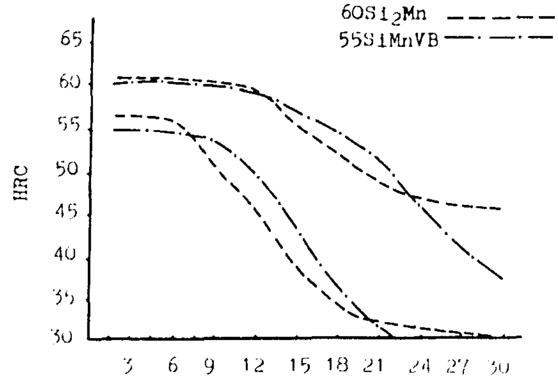

Fig.2 Hardenability band of 55SiMnVB and $60Si_2Mn$

DESIGN OF THE LEAF SPRING SUSPENSION

Design factors that favour longer spring fatigue life are exploited to decrease specific stress. These are: properly increase the length of the spring leaves, and properly increase the thicknesses while reducing the number of leaves.

Proper increase of designed static stress of the spring within the strength capacity of the material will decrease the stiffness of the leaf spring assembly as well as the uncoupled natural frequency of the vehicle, thus will improve vehicle ride.

The traditional rectangular cross sectional leaves are replaced by leaves with double grooves roll-formed on the compression side (Fig.3) with the result that the neutral layer of leaf is shifted towards the tensile stress side. This gives rise to unsymmetrical stress distribution across the leaf thickness. Therefore, the maximum tensile stress in the leaf is always smaller than the maximum compressive stress in operation. As fatigue failure always initiates at the tensile side, our measure to cooperate the double grooves on the compression side so that the ratio of maximum tensile to maximum compressive stress is in the range of 0.839 - 0.845 : 1 will finally reflect in a saving of material and vehicle curb weight.

To compare with another version with only a single groove, the double grooved one can be better assembled and held in place with the help of riveted clamps without the necessity of tapering of the leaf-ends. This is of special significance when applied to thinner leaves(2).

Table 2 shows the comparision of several leaf spring assemblies for vehicle with similar gross weight and loading capacities.

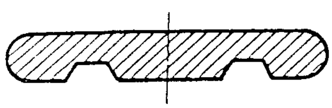

Fig.3 Cross section of the double grooved spring leaf

Table 2

MODLE	CROSS SECTION	NOMINAL LOAD CAPACITY (kg)	TOTAL WEIGHT OF VEHICLE SPRING ASSEMBLIES (kg)	LOAD/WEIGHT OF SPRING
EQ140	with double grooves	5000	246.6*	20.3
EQ140	rectangular	5000	275.6*	18.14
CA10	rectangular	4000	240	16.65

* Weight of cast iron hangers of the leaf spring suspension assembly is also included

For the same vehicle modle EQ140, it is indicated in table 2 that the double grooved type saves 10.5% of the gross weight of spring assemblies compared with the rectangular one.

It is also found in practice that for double grooved springs, the leaf deflects in such a way that lateral warpage is either reduced or eliminated. This tends to alleviate stress concentration and improve contacts between leaves, which constitue one of the reasons for longer fatigue life of spring assemblies.

Polyformaldehyde plastics is employed to make spring eye bushings. The use of this material has prolonged the service life of the assemblies, and also reduces the gross assembly weight. The bushings are better than bronze or powdered metal bushings.

MANUFACTURING TECHNIQUE

A series of advanced, reliable manufacturing techniques have been employed, which plays an important role to ensure good quality and long service life of the final product, as well as effectively improve working conditions of workers.

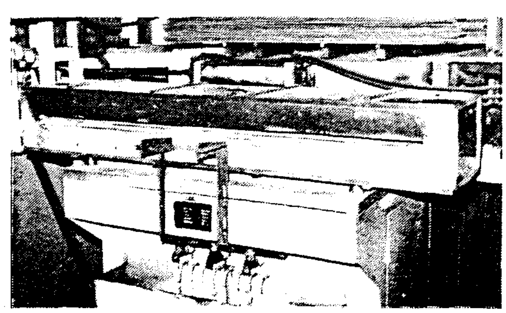

Fig.4 Medium frequency induction heating set-up of spring leaves

Applied to the heating process for quenching, the induction heating with medium frequency range,(IHMFR for short)

(Fig.4) offers the following advantages; short heating time, very thin oxidized surface layer, with little increase of surface decarburization depth and, hence, long service life spring leaves. As compared with other traditional heating methods IHMFR has eliminated the time used for preheating of both furnaces and spring material, thus its flexible in production planning. With stable heating parameters, IHMFR set-up can be put into continuous production soon after the adjustment of the system is accomplished. This guarantees fine crystal grain structure of leaf spring after quenching.

This heating method emits no strong radiation, nor environmental contamination. The working environment has been so improved that the hygienic appearance of the workshop has been greatly renewed. One of the significant merit in adopting IHMFR technique lies in the fact that the heating efficiency is higher than 60%, which obviously means a some energy saving.

Fig.5 Hydraulic forming machines for quenching with semi-automatic rocking

The quenching process employs a specially-designed hydraulic semi-automatic rock-quenching machines(Fig.5). That machine clamps a spring leaf automatically, dips it into the quenching medium with a rocking motion, then releases it and lifts up for next working cycle. This quenching method not only results in good cooling effect, but also is easier to adjust and ensures stable leaf shape after quenching.

A continuous passing through tempering furnace yields high production efficiency and stable product quality. The hardness variation of the leaves can be controlled generally within HRC2 and for the same leaf, generally within HRC1 (3).

The pre-stress shot peening process can change micro texture of the surface layer, eliminate drop of strength due to surface defects, if any on some leaves, and thus greatly enhance mechanical properties of the spring assemblies. A high residual compressive stress (measured up to 588 MPa) is imposed on the leaf surface subjected to tensile load (4). It is this compressive residual stress on the tensile surface of the leaves that helps the leaf spring assembly to survive for a long service life.

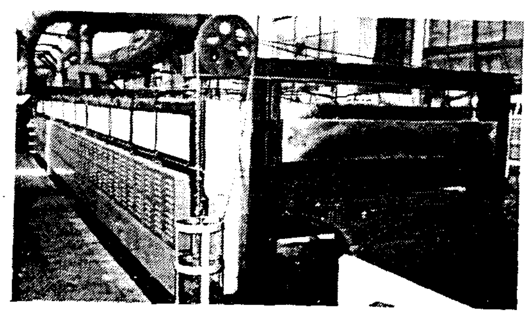

Fig.6 Continuous passing-through tempering furnace

The changed surface texture alleviates the propagation speed of micro-fatigue cracks on the leaf surface, hence, prolongs the useful life of spring.

Shot-peening treatments can be

classified as unstressed and pre-stressed. By unstressed is meant that the shot peening is applied when the leaves are in a free state; while the pre-stressed one means that the leaves are shot peened at the tensile surface when they are subjected to a tensile load during peening.

The leaf springs produced by SAW have all been through the pre-stressed shot-peening treatment. The shot-peening, esp., pre-stressed shot-peening treatment has a significant role in improving fatigue life of the individual leaf. Our experimental work has shown so:

(1) Compared to the unpeened leaf, the unstressed shot-peening treatment increases leaf fatigue life up to 166%;

(2) The pre-stressed shot peened laaf can reach a fatigue life 2 to 7 times as long as that of the leaf processed with unstressed shot-peening treatment, depending upon the residual stress implanted in the leaf while peening.

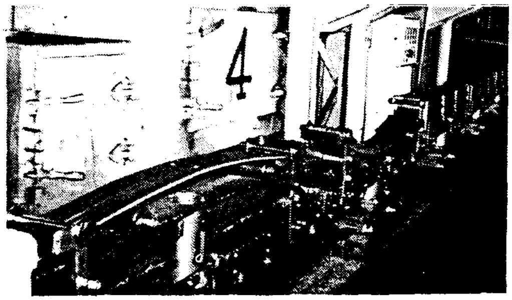

Fig.7 Pre-stressed shot-peening set-up

Single leaves are assembled into a leaf spring assembly and a pre-compression treatment of the assembly is applied, as show in Fig.7. The pre-compression treatment produces local permanent plastic deflection of leaves(5).

This deflection stabilized the height of the spring assembly and also improves contacts between leaves. The resultant increase in the residual compression stress on the tension surface of the leaves is also favorable to the spring fatigue life(6).

Fig.8 Spring assembly pre-compression

After the assemblage is completed, the assembly is hung on a continuous chain conveyor for coating and drying processed.

The electrostatic coating with infra-red take only 20 - 30 minutes. It raises the production efficiency, makes the operation of workers convenient and improves working environment. The resulted coating film is film is firm and bright.

Fig.9 Spring electrostatic coating and infra-red drying line

CONCLUDING REMARKS

SAW conducted R & D work of spring

manufacture in late 60's and incorporated the results in her plant design.

Leaf spring thus produced have obtained good customer reception, from home and abroad, not only in vehicle ride, but also in a good service life. More than half a million on- and off-road trucks with double grooved leaf springs of steel 55SiMnVB are now in service.

Spring assemblies for spare parts market of other vehicle designs are also produced in these production lines as the production method and facilities are quite versatile.

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