The Use of Specialised Shot Peening Techniques on Tapered Leaf Suspension Springs for Road Vehicles

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ABSTRACT

Techniques have been put into practice which allow the design of springs to stresses up to 40% higher than those used in the design of conventional leaf springs. The paper describes the processes used, the fatigue life potential and relates these to the residual stresses attainable, with particular emphasis on real life case studies.

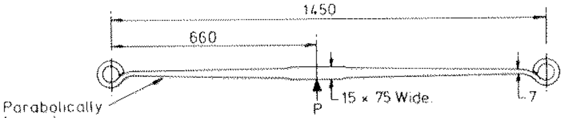
KEY WORDS

Tapered leaf springs - Taperlite springs
Fatigue strength
Strain peening - Presetting

Introduction

British Steel Corporation carried out fundamental development work in the early 1960's resulting in the first European use of Tapered leaf springs. The Taperlite spring embodies a specially developed pre-setting and strain peening technique which results in extended fatigue life well in excess of that attainable with free peening. Since 1967 in excess of 5 million springs comprising 300 part numbers have been produced using the method described, with high durability and relaxation resistance coupled with reduced weight and improved ride. Such springs range from passenger car applications of approximately 4 Kg weight to heavy commercial vehicle springs 2 metres in length weighing 100 Kg and also include railway applications.

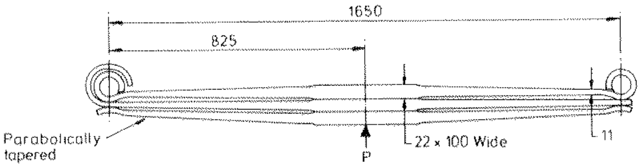
The method can best be described through case studies, for which have been chosen a light van single leaf spring (fig. 1) and a heavy commercial vehicle 3 leaf spring (fig. 2).



	P	Stress
Static	4120 N	706 MPa
Jounce	6620 N	1140 MPa

Rate	Weight
24.5 N/mm	9kg

Fig. 1



	P	Stress
Static	29420 N	610 MPa
Jounce	58840 N	1220MPa

Rate	Weight
245 N/mm	62 kg

Fig 2

THE PRINCIPAL FEATURES OF THE MANUFACTURING PROCESSES ARE:-

i) Leaf Tapering by hot rolling to a parabolic profile for uniformity of stress along the leaf in service and during presetting.

ii) Austenitising, bending to shape, hardening by oil quenching followed by tempering.

iii) Presetting each leaf individually to at least twice yield strain to elevate the elastic limit as shown in Fig. 3a.

iv) Strain peening at approximately twice yield strain with each leaf held on a custom designed bearer as shown in Fig. 4. Peening medium S.660 cast steel shot giving a minimum Almen intensity of 25C (mm).

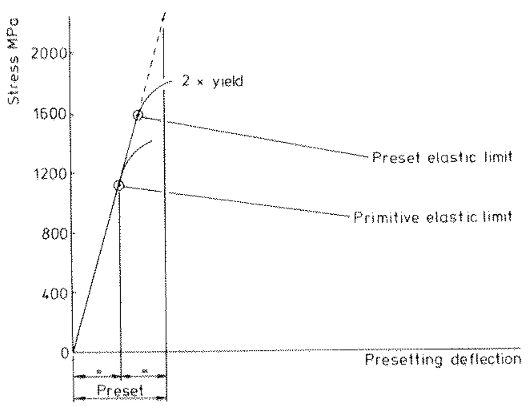


Fig 3a

Graph showing difference between a spring
Preset to its yield point and one to double the amount

The presetting and strain peening operation result in large camber height losses, see Fig. 3b, which necessitate high as-bent cambers and specially designed plant. The exact camber losses have to be calculated and then controlled in manufacture to achieve finished cambers and loads as specified by the end user.

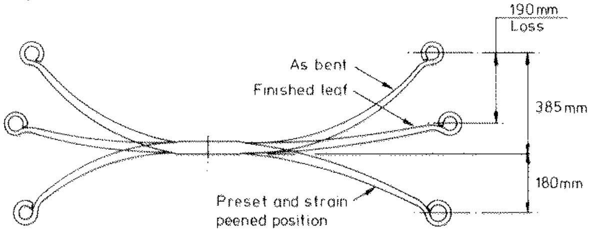
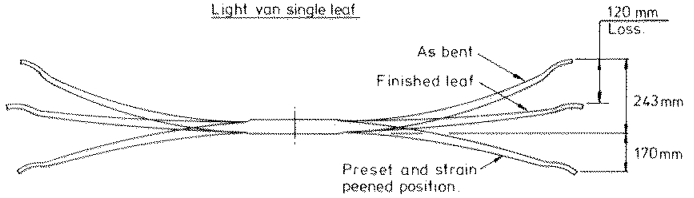


Fig 3.b. Light van single leaf



3rd leaf of heavy commercial vehicle spring

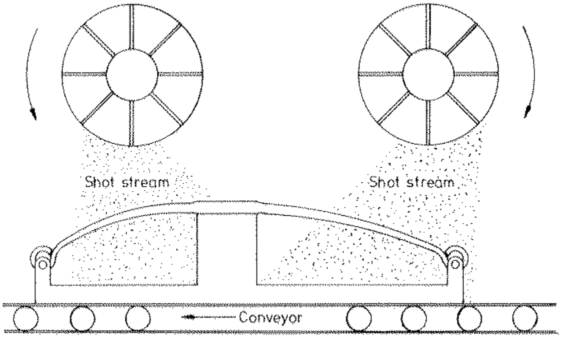


Fig 4 Spring on custom designed bearer being shot peened

DESIGN & RESIDUAL STRESS LEVELS

The benefits of this process are the ability to work to high stresses without relaxation problems and to provide a high standard of durability. Design stresses are normally limited to 700 MPa static laden and kept within dynamic limits as indicated by Fig. 5.

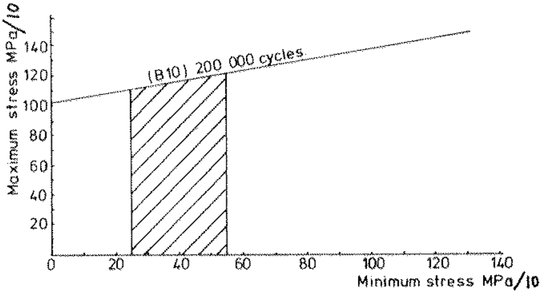


Fig 5. Permissible design stresses.

The Taperlite spring is most commonly employed in the suspension of commercial vehicles where leaf thicknesses of 20 to 40 mm are typically employed in designs of one to four leaves. The process described is particularly effective in promoting fatigue life in such springs due to the level and depth of residual stress imparted. A typical result of residual stress determination is shown in Fig. 6 (ref. 1) where compressive residual stresses of up to 1700 MPa are achieved at depths of 0.25mm below the surface of the leaf normally subject to tensile stresses in service. The actual surface stress reduces to 750 MPa the latter having been determined by means of X-ray methods, whereas the body stresses are obtained by "layer - removal" techniques.

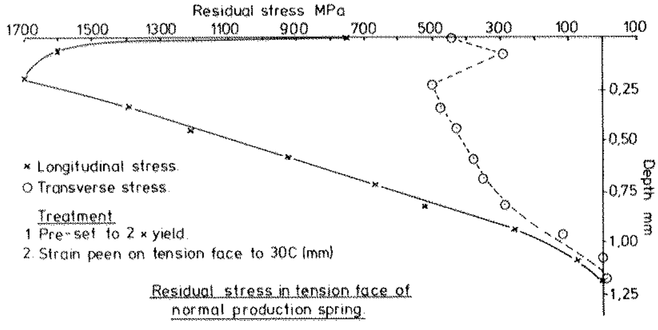


Fig 6. Residual stress in tension face of normal production spring.

The level of presetting not only confers improved relaxation resistance but coupled with an almost equally high level of strain during the strain peening process develops an optimised fatigue rig performance and exceptionally good service life judged to be 3 x that of conventional Laminated springs. Comparative tests have indicated a link between long life and high residual stress, the latter increasing as the level of strain increases. A Rigaku strain - Flex machine is currently used to assess the surface residual stresses achieved on production springs fatigue tested as part of an in-house quality assurance programme. Some typical longitudinal results are shown in table 1, and in one example the normal production technique is compared with a free peened leaf to illustrate the scale of difference both in fatigue life and residual stress.

TABLE 1

Spring Type	Pre-Stressing Details	Rig Test Details			Longitudinal surface Residual Stress MPa
		Rebound Stress MPa	Bump Stress MPa	Result	
Single Leaf Spring	Normal production strain peen.	476	1243	317,740 cycles	$-783\ ^{+6}_{-2}$
	Experimental free peen.	As above	As above	66,659 cycles	$-353\ ^{+9}_{-2}$
Single Leaf Van Spring	Normal production strain peen.	445	1193	532,796 cycles	-877 ± 14
2 Leaf Truck Spring	Normal production strain peen.	472	1213	unbroken 248,017 cycles	$-677\ ^{+16}_{-2}$ (result on main leaf)

Such rig tests are preferably run to failure to enable statistical data to be built up and examination of the fractures. In theory, failure should initiate at a position below the surface where the sum of the tensile stresses from prestressing and imposed loading is at its maximum, but in practice tension surface failures occur where metallurgical imperfections are present.

Rig tested springs fail by relatively rapid fatigue near or on the edge of the section, and therefore strict attention has to be paid to achieving good coverage over the width of the leaf and its corners. Service failures, when they do occur have a more well developed area of fatigue and are less likely to be initiated at the corners and edges.

STEEL COMPOSITIONS

SAE 5160 and SAE 4161 are used for these springs, the particular grade being chosen on hardenability criteria to ensure through-hardening to a minimum of 80% martensite at the centre of the thickest part of the spring by normal oil quenching. Tempering is controlled to give a uniform hardness within the range 415/461 BHN (1350 - 1550 MPa UTS). The surface is "as rolled" but heating and rolling conditions are controlled to ensure freedom from excessive defects and decarburisation because of their influence on fatigue property.

Further developments with such springs are foreseen with the ever increasing demand for weight savings. The present development activity centres on improved controls over shot peening to enable further optimisation of the process and possible use of even higher stresses for selected applications.

REFERENCES

1. Babb, Haynes, Middleton/Sub Surface Residual Stresses in Taperlite springs/BSC Ref. No. SH/PROD/ENG/8702/-80/D.

Taperlite is a registered trade mark of the British Steel Corporation.