Note 66

The 'Standard' Grand Prix suspension

(The contributions of Hubert Charles, Charles and John Cooper, and Colin Chapman)

Insofar as a modem Grand Prix car, with vast aero downforce, has any suspension – *"grovelling around a few millimetres above the road"**, as Keith Duckworth once remarked acidly, and then being rammed over kerbs with dampers solid in shock to prevent the all important floor from being torn off the car - its basic layout goes back to the R-type MG of1935.

The R-type MG

At that date Hubert Charles designed a racing chassis suspension which differed completely, not only from the rigid-axled layouts of all successful pre-1934 racing cars and previous MGs, but also from the 'new order' introduced to GPs in 1934 by Mercedes-Benz and Auto-Union. These latter cars had independent front and rear suspension (IFS and IRS) with an inclined roll axis, low front/high rear, giving an oversteer characteristic very embarrassing with high power/weight ratio. Charles' solution was double transverse links at each corner. With links initially parallel to the road, the roll axis was at ground level. Front and rear suspensions were connected by a very stiff box-backbone chassis. A somewhat high centre-of-gravity (CG) height/track ratio meant that the R-type rolled considerably on corners (a photo shows an outer front wheel at 10^0 positive camber on a Brooklands 'road' circuit hairpin (810)), to the unease of drivers used to near-flat cornering and, admittedly, to the reduction of cornering force from the positively-cambered wheels. There was also teething trouble with the dampers. However, wheels which leaned but which stayed on the road over the bumps of pre- WW2 circuits, because of the reduction of unsprung weight, were greatly preferable to rigid-axle wheels hopping into the air (139)! It is certain that the drivers would have got used to the roll in time** and would then have appreciated the above-mentioned and other advantages of IFS and IRS plus the stable steering. Unfortunately, Lord Nuffield had lost his limited enthusiasm for motor-racing after the accidental death of an MG mechanic in 1934, sold his personally owned MG Co to his parent group in 1935 and then permitted Leonard Lord (Group Managing Director) to close the racing department abruptly only two months after the R-type debut (806). The car, therefore, had no chance to show what it could do after the skilful development which Charles could have carried out. His plans for an 'active' Mk 2 R-type, in which a gyroscope would have commanded hydraulic cylinders to move the longitudinal torsion-bar spring-stops and jack the chassis against roll (806) might have been too elaborate for the '30s but transverse roll-stiffening torsion bars at each end were not beyond his brilliant mind. Knowledge was just coming across the Atlantic of Maurice Olley's experiments in the USA where, in 1933, an experimental Cadillac had been fitted with a front bar to alter the steering characteristic (807). Of course, such bars *do* convert IFS and IRS into semi-independent systems and in proportion to their stiffness do bring back some of the rigid-axle disadvantages but this point will not be laboured here!

The Cooper 500

The R-type was a very promising idea, which did not progress through no fault of its own. A racing mechanic of its era, Charles Cooper, must have been familiar with it. It would be stretching the connection too far to suggest that it was in his mind when, post-WW2, he and his son, John, built their first 500cc car. The availability of several IFS units from scrapped pre-WW2 Fiat 500 'Topolino' road cars was no doubt the deciding factor, this IFS having double transverse links for each wheel made up of a lower wishbone and an upper centrally-mounted transverse leaf spring - but the stroke of genius was to use these assemblies at each end!

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* Admittedly regulation changes since 1993 have forced cars a little further off the road!

** As Michael Hawthorn did in the 1952 Cooper-Bristol, qv.

This layout, gradually refined in springing and links location by the Coopers with Owen Maddock (their only designer) and later with the input of Jack Brabham when he became their No 1 driver, was the unique 'trademark' of all Cooper cars for the next two decades. It became the 'standard' way to suspend a Grand Prix car from 1960. The mid-engined layout also pioneered post-WW2 by the Coopers (except for the 1952-1953 F2 cars and a few sports cars) kept the CG height/track ratio fairly low and so the roll angle *could* be much less than the MG R-type. However, a photo shows a 1952 front-engined Cooper-Bristol (high CG) cornering at speed in the hands of Hawthorn with 7° of positive camber on the outer wheels (see Fig. N66A on P.4) and another of a 1952 500cc car (lower CG) driven by Eric Brandon with 8° (Fig. N66B). These figures can be compared with a 1951 Alfa Romeo 159 in a full-blooded power-slide by Fangio in the British GP having 4° positive camber on the outer front wheel and 0° on the outer rear - this particular car retaining swing-rear-axle set up statically with negative camber (Fig. N66C)

Reducing the roll angle

Steps, therefore, were taken gradually by the Coopers to reduce this roll. The 1953 500cc chassis picked up the post-WW2 Fiat 600 *semi-IFS* improvement with the transverse leaf spring held between two spaced-apart roller mountings, plus a central lateral location with vertical freedom, so as to give a higher spring rate for roll than in pitch; the 1954 500cc Mark 8 applied this scheme at both ends*. The system was continued on larger-engined cars until their higher speeds called for IFS by double wishbones and coil springs with a torsional roll-stiffening bar (hereafter 'anti-roll' bar) in early 1958 (type 45). Shortly afterwards double wishbones were adopted at the rear, although still with the roll-stiffened transverse leaf spring. This car, with which Jack Brabham won his 1st Championship, cornered at speed with roughly half the outer wheel angle - 4° - of the earlier types mentioned, although Stirling Moss in a 1959 car 'in extremis' while trying in an early 1960 race to catch a new Lotus 18 was photographed at 6° with the inside front wheel off the ground (Fig. N66D) - but a wishbone broke after he took the lead (1043).

The Lotus 18

The Ll8 was Colin Chapman's Cooper-inspired first mid-engined chassis with double wishbones, coil springs and anti-roll bars at each corner. The Lotus outer front wheel angle in the photograph mentioned was 3°. The Coopers, having seen earlier L18 performances in 1960, had already designed the new lower T53, in which the IRS was made basically the same as the 1958/1959 IFS. Brabham won a 2nd Championship with this. Illustrations on P.5 show the Cooper improvements from 1957 to 1961.

Thereafter, while there might be more widely-spaced wishbone elements to reduce loads and so permit lighter parts - eg the L18 rear suspension, which also used fixed-length jointed half shafts to double as wishbone elements (812)** - the 'standard' suspension pattern for GP cars had been established.

Given the basic 'double transverse link at each corner' formula, detailed variations could be used: relative lengths of upper and lower links; front/rear anti-roll bar relative stiffness rates; front/rear weight distribution; tyre sizes and pressures; damper settings; cambers. Some would be fixed at the design stage, some could be varied at the circuits to produce a steering characteristic which (at least attempted!) to satisfy a driver's wishes.

The desirable steering characteristic

Laurence Pomeroy, writing in mid-1963 (804) gave Colin Chapman the credit for being the first racing chassis designer with his L18 *"consciously ... to deduce that the optimum solution*

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* Bob Gerard applied torsional roll-stiffening bars to each end of his front-engined Cooper-Bristol at about the same date.

** The LI8 rear followed Frank Nichol's 1958 Elva Mk 4 sports car layout, also used on Eric Broadley's 1958 Lola sports car. It appears that the use of a fixed-length half shaft as a suspension element had been patented by Georges Roesch in 1934 (814)!

was tameable over-steer. which the super-driver could induce at will by braking or accelerating". Actually Jack Brabham, the No 1 Cooper driver and World Champion in 1959 and 1960, was already on record as preferring mild under-steer provided that there was sufficient power to create over-steer on demand (811).

Later in 1963 Pomeroy acknowledged (32) that Rudolf Uhlenhaut had modified the Mercedes-Benz W196 before the 1955 season to have neutral-to-final over-steer instead of the strong 1954 under-steer. He also accepted that the Ferrari and Maserati designers of the '50s achieved the same final over-steer characteristic - but felt, perhaps, that in their cases (to quote from the Foreword of this review) it was *"a mixture of Inspiration ... and Experience"* and that Chapman had inserted '*Calculation*' into this mixture at the design stage.

That the desired end result could be achieved in more ways than one by the details in producing the 'now standard' GP chassis was illustrated by Stirling Moss in describing (32) (815 provides the details) how he was able to lap Warwick Farm circuit (in Australia) in February 1962 1% faster in a 'lowline' 1960-type T53 Cooper than a 1961 Lotus 21. The former had a 2.7L FPF, however, and the latter a 2.5L, and that must have been worth a couple of percent around the twisty course. Moss conceded that the Lotus would probably have been faster, driven with complete attention, whereas the Cooper was more forgiving and could be 'thrown' around*.

What was being realised consciously at this date in racing car design was the application of the 'Natural Rule of Thumb' well-known in aeronautical circles, whose particular derivative for vehicles is:-

$$\frac{\text{Stability x Control}}{\text{Complexity}} = \text{Constant}^{**}$$

(To visit 'Natural Rule of Thumb' click here:- grandprixengines.co.uk/Natural_Rule.pdf)

Technical revolution from minimal resources

It remains only to be recorded that (what has been entitled) 'The Cooper Revolution', of a mid-engined car with a winning mixture of stability and control, was produced by father and son and Owen Maddock from a tiny organisation with no greater resources than a small repair garage and which bought its own engines. Of course, as they and their drivers worked their way to the top, they did benefit from the free development strengths of Coventry Climax engines and Dunlop tyres, plus a subsidy from Esso to pay Brabham's salary (813).

Note 66 Illustrations.pdf

This linked companion section provides illustrations as follows:-
1935 MG R-type; 1946 The first two COOPER 500s; 1960 COOPER T53; 1960 LOTUS MK18;
1967 LOTUS MK49; 1978 LOTUS MK79; 1989 WILLIAMS FW 12C;
1996 FERRARI F 310; 1997 FERRARI F 310B; 2013 MERCEDES-BENZ AMG W04.

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* This was the last occasion on which a super-driver could compare two state-of-the-art cars from different makers, because both belonged to the last of the grand independent team owners, Rob Walker.

** This had been seen in the contrasting fighter aircraft pairs of 1917 and 1940: in WWl SE5A (stable, 'under-steer', a good gun platform) v. Camel (unstable, 'over-steer', easily manoeuvred in a dogfight - by pilots with exceptional reactions, ie 'super drivers'); in WW2 Hurricane (‚under-steerer') v. Spitfire ('over-steerer').

Fig. N66A
1952 Cooper-Bristol T20
Michael Hawthorn at Goodwood, Easter Monday, winning the F2 race
DASO 483-2 *The Racing Coopers.* A. Owen. Cassell. 2nd Ed. 1959.

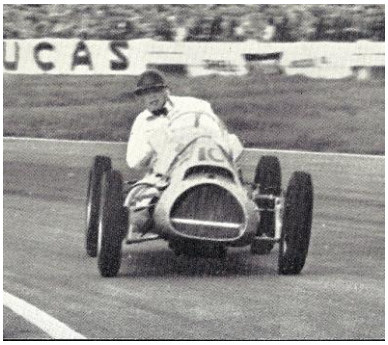


Fig. N66B
1952 Cooper-Norton 500 cc MkVI
Eric Brandon at Goodwood.

DASO 808

Fig. N66C
1951 Alfa Romeo 159
Juan Fangio at Silverstone.
DASO 809

Fig. N66D
1959 Cooper T51 versus 1960 Lotus Mk 18
Innes Ireland leading Stirling Moss in the 1960 International Trophy at Silverstone.
DASO 1043

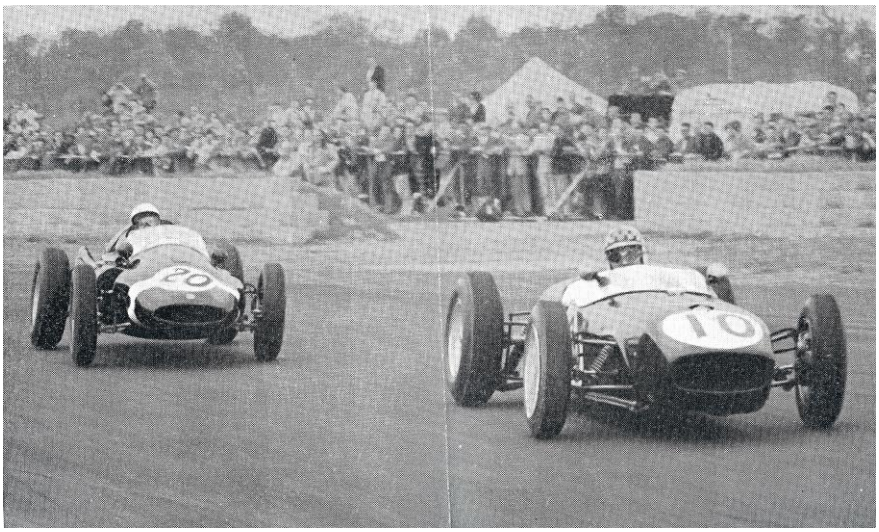
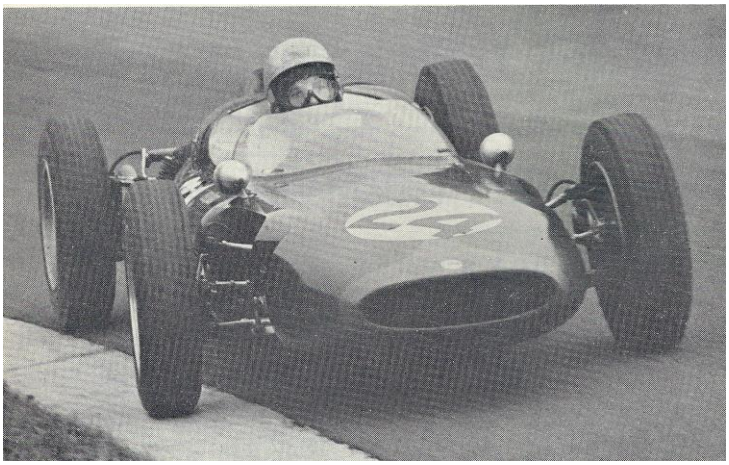


Fig. N66E
1957 Cooper Climax T42 Formula 2
Coventry Climax FPF 1½L engine.
The photograph below, showing Jack Brabham on Woodcote corner at Goodwood, was published on the front cover of the magazine *Motor Racing* for November 1957 (DASO 506).
Brabham wrote in ref. (811), published in 1960, "*I could see that the Cooper suspension needed a lot of attention.* [It] *showed that the car had much too much body roll, the wheels.... were leaning badly.....When we went over to the double wishbone car in 1958* [these photographs were] *invaluable in helping to rectify the Cooper suspension*".

The car is in an oversteering slide with the driver applying some opposite lock.

Fig. N66F
1961 Cooper Climax T53 Formula 1
Coventry Climax FPF Mk2 1½L engine.
This photograph shows John Surtees in a Yeoman Credit-owned T53 with the FPF MK2 engine to the new formula in the Belgian GP on the climbing RH corner just beyond Eau Rouge, i.e. at very high speed. The suspension is compressed by the inertia load.
The improvement in the car's cornering with the "low-line" T53 chassis is clear
DASO *Motor Racing* August 1961



The car is in an understeering 4-wheel drift.

Surtees finished 5th, the first car after four Ferrari 156s which had up to 30 HP more power.