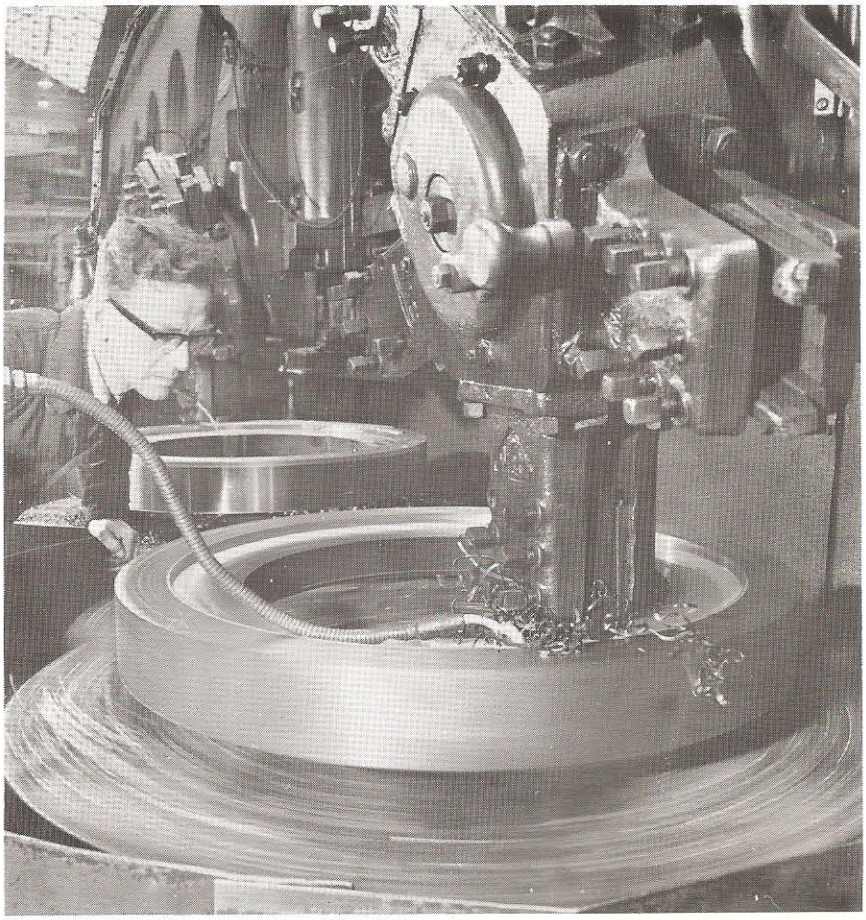
The manufacture of gearwheels and pinions

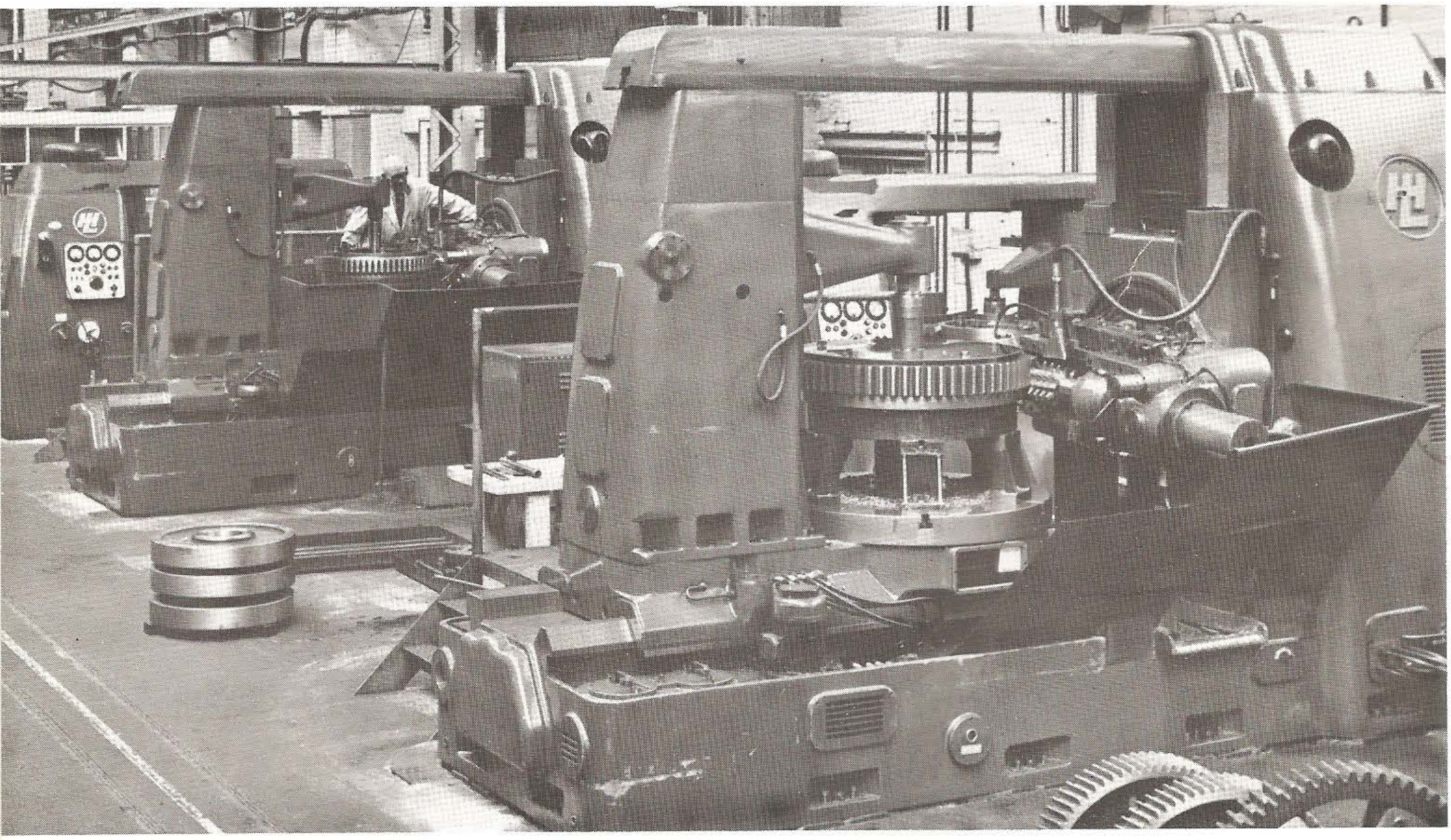
GEC Traction Limited

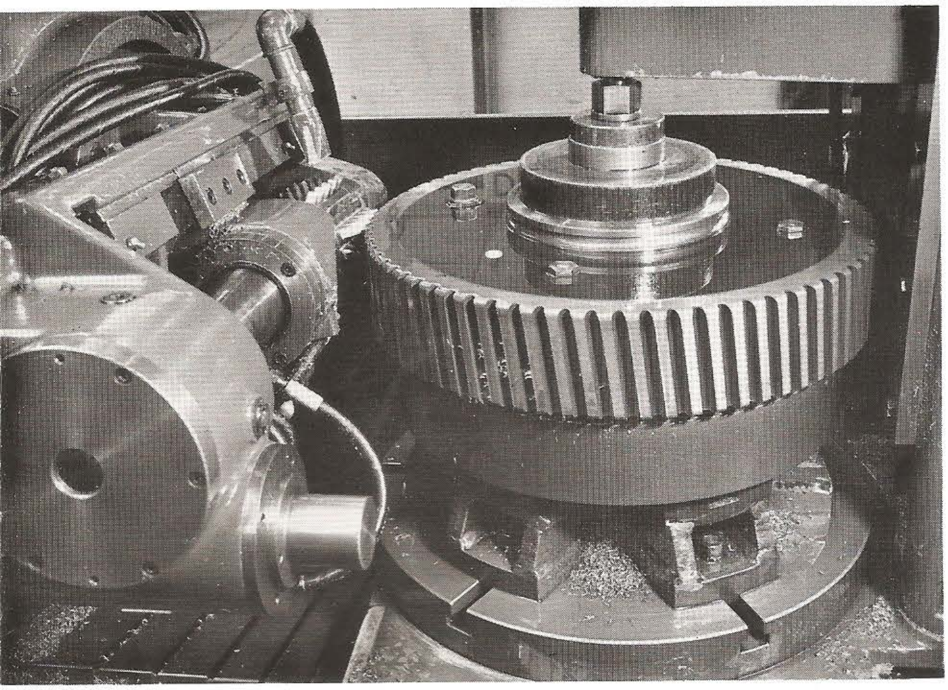
The manufacture of traction gears

The rapidly increasing use of electric and diesel-electric rolling stock on railways during the past few years has been reflected in the expansion of traction gear manufacture. Resilient gearwheels, which are used on many high speed locomotives, are now made in as great a quantity as solid gearwheels. The resilience between the rim and centre part of these wheels is provided by a number of Silentbloc bushes. A specially formulated rubber has been developed for the bushes, enabling the gearwheels to function for prolonged periods without deterioration, in the presence of gear lubricant at elevated temperature. Most pinions are still designed to seat on the tapered shaft extensions of axle hung motors. However, to take full advantage of modern high speed motors, it may be necessary to select a gear ratio involving a pinion too small to be mounted in this way. In such cases the pinions are manufactured with an integral shaft extension which plugs into a corresponding socket in the motor armature shaft. Gearboxes with two stages of reduction are made for locomotives designed to produce very high tractive efforts at relatively low operating speeds.

The more important features of gear manufacture at GEC Traction works are illustrated in this article.







A single helical gearwheel being hobbed. The helix angle is 7½°, a standard frequently adopted in order to limit the end thrust on the armature bearings.

Rims for resilient gearwheels being turned prior to tooth cutting on hobbing machines. Two rims can be turned simultaneously on the duplex machine illustrated.

Two 1000 mm (40 in) diameter gearwheels being cut on automatic hobbing machines. One operator is able to supervise the operation of two of these machines.

Turning and tooth cutting

The gear blanks are normally supplied as rough machined forgings and are turned, prior to tooth cutting, on standard boring machines and turret lathes. Accuracy of the locating diameters used in later manufacturing operations is carefully controlled.

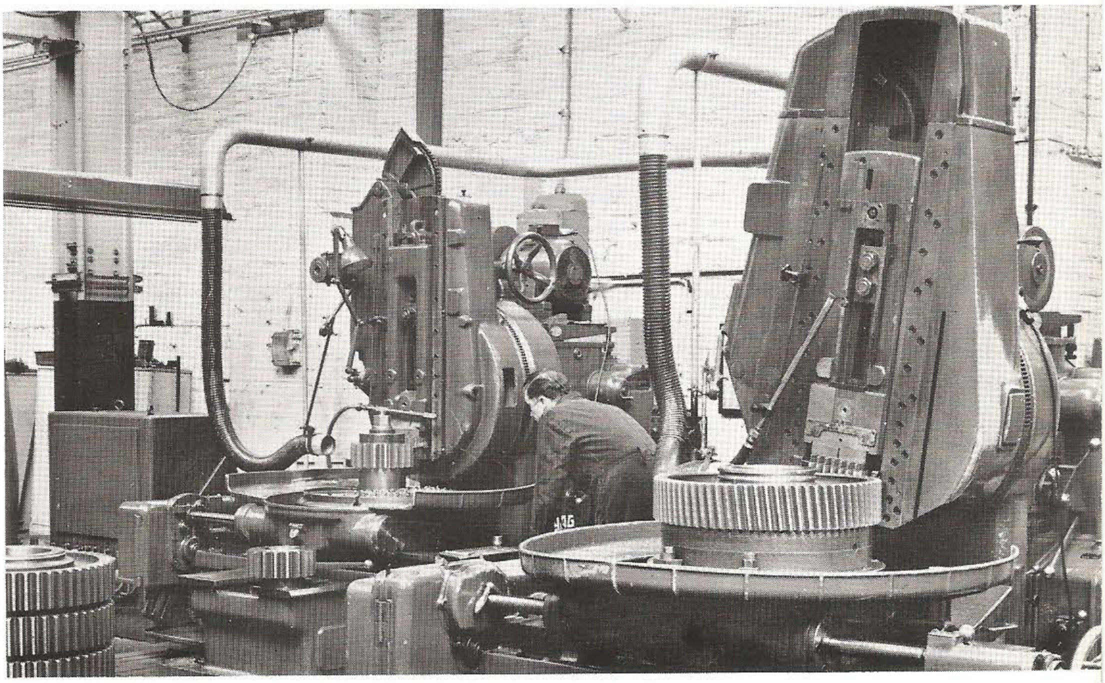
The high speed hobbing machines, which are used, are characterised by their great rigidity. This is necessary for cutting materials with tensile strengths of 65-70 tons/in^2 at a single pass of the hob. The machines may be operated automatically on a pre-set cycle and can cut gears up to a maximum diameter of 1500 mm (60 in). One of the machines is equipped with a copying device which enables crowned or taper teeth to be cut with reproducible accuracy.

The cost of the special hobs required for most traction applications may add substantially to the manufacturing cost if only small numbers of gears are needed. In these circumstances it is more economical to cut the teeth on gear shapers which generate the required involute form using simple rack-type cutters.

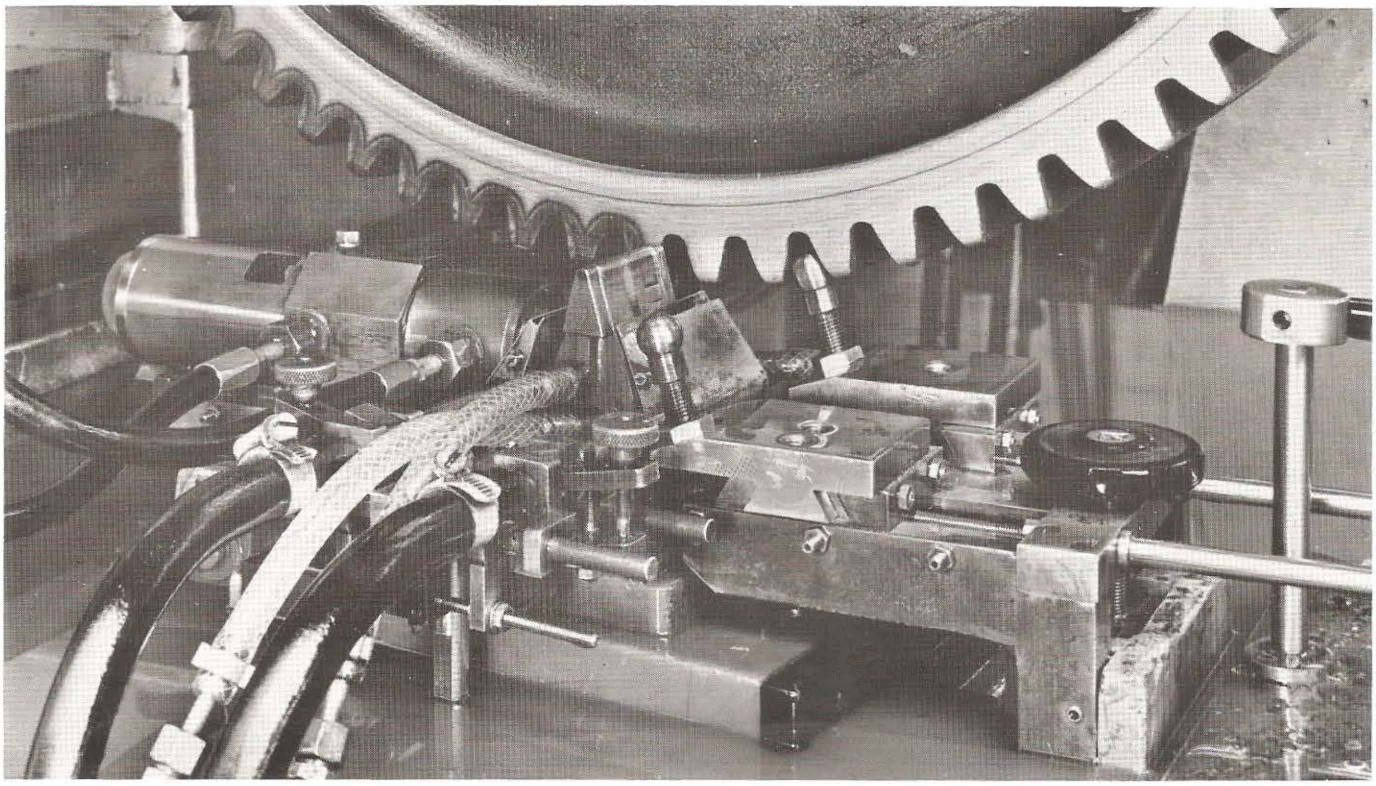
Considerable work has been carried out on rack cutter and hob design, particularly in respect of providing protuberance. This gives slight undercutting of the gear teeth which not only facilitates subsequent profile grinding but, by virtue of eliminating the grinding of the root fillet leaves this surface in its most desirable state of compressive stress resulting from heat treatment. Traction gears require large grinding allowances, in some cases as high as 0·5 mm (0·02 in) per flank.

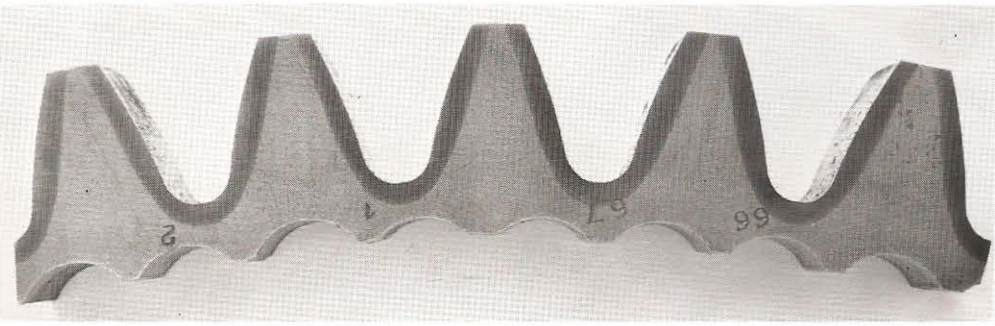
Induction hardening

Induction hardening has been introduced to supplement heat treatment facilities after some years of experimental development, during which the 'single shot' and 'tooth-by-tooth' principles were evaluated. The single shot method involves the rotation of the gearwheel within a concentric conductor carrying a high frequency current. Induced currents in the peripheral 'skin' of the gearwheel rapidly heat these surfaces, which may then be quenched in orthodox ways to produce the required hardness. The tooth-by-tooth principle employs a current carrying inductor shaped to conform with the contour of a single tooth or, more usually, with the gap between two adjacent teeth, so that the tooth flanks and root are heated simultaneously. Whilst both principles have their advantages, the tooth-by-tooth method has proved better suited to traction requirements.



Two gear shaping machines cutting teeth with rack-type cutters. The heads of the machines can be inclined, as with the nearer machine here, to cut helical teeth.





The apparatus used for induction hardening gear teeth. The quenchant tank has been lowered to show the hardening head, the indexing mechanism and the inductor.

A section of gear teeth cut from an induction hardened gearwheel and etched to show the hardened areas.

The induction hardening machine used is supplied by a generator with an output capacity of 75kVA at 10kc/s. At this frequency a hardened case of adequate depth is readily obtained on tooth sizes of between 2 and 4 diametral pitch, which satisfactorily covers all normal traction requirements. Both spur and helical gears may be hardened in this manner. Throughout the hardening cycle the teeth under treatment are submerged in the quenching bath, so that heating is substantially confined to the zone within the immediate influence of the inductor as it traverses the tooth valleys. As the inductor moves forward its place is quickly re-occupied by the quenchant, thus reducing to a minimum the duration of the heating and quenching cycle. Additional cooling of the teeth is provided by jets which play on the tooth tips and flanks immediately adjacent to those being hardened. In combination, these features preserve the overall rigidity of the gearwheel during the hardening process, keeping distortion within limits and dispensing with the necessity for corrective grinding for many applications.

The physical characteristics of an induction hardened gear closely resemble those obtained by the more traditional methods of case hardening, with the tooth flanks and roots hardened to a predetermined depth. A choice of materials is available and by suitable selection it is possible to achieve the desired properties in the case and core within closely controlled limits. Normally, the core properties are established by heat treatment before the gears are machined to their final dimensions. Subsequent treatment of the tooth surfaces by the process described produces a case of depth and hardness similar to that of a carburised gear.

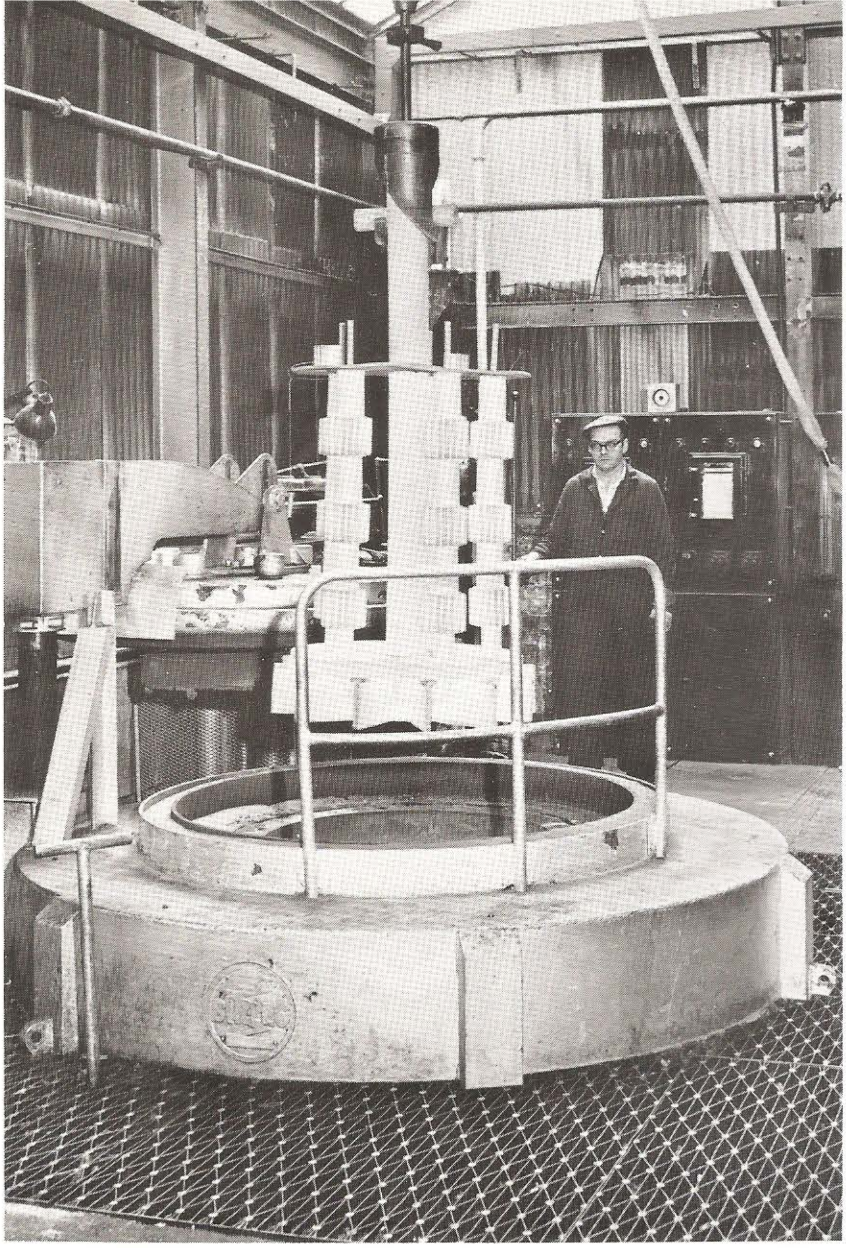
Normal heat treatment

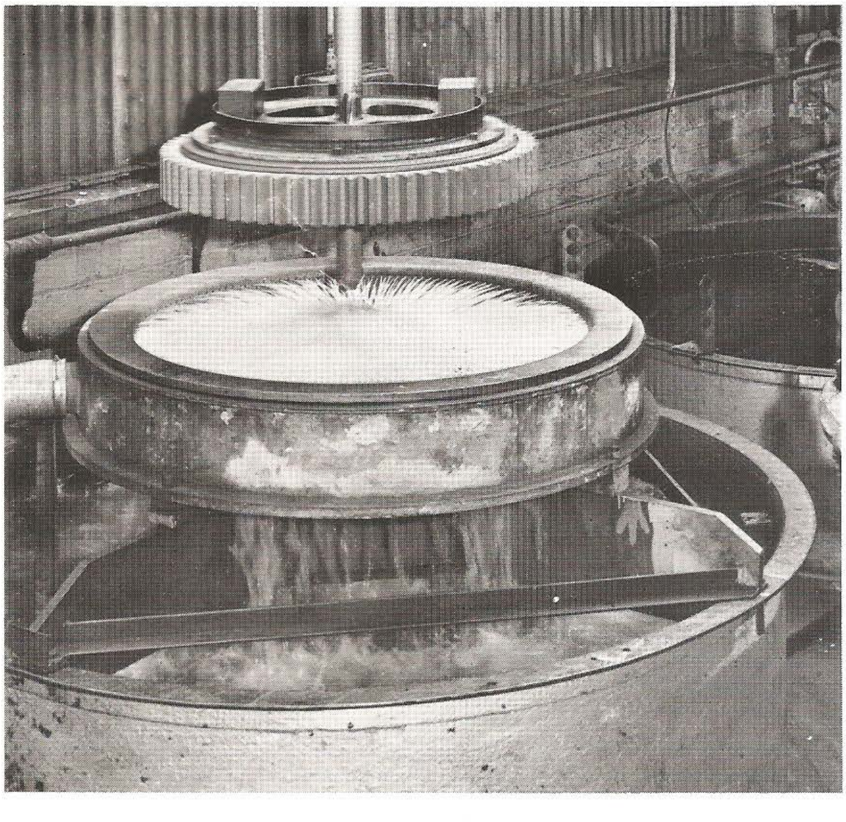
Heat treatment is also carried out in its more traditional forms, and electric heating and tempering furnaces together with a gas carburising furnace, all manufactured by GEC Birlec Limited, are installed. Heating is carried out in a controlled atmosphere to avoid oxidation or decarburisation, either of which is detrimental to the hardening process.

Above right A charge of shaft pinions being removed from the gas carburising furnace. When cooled they are machined to remove the carburised surfaces from areas which do not need to be fully hardened. They are then reheated to hardening temperature and quenched.

Right A resilient gearwheel rim about to be quenched in the spray ring. Successful hardening is dependent upon a closely controlled time cycle.

Far right The teeth of a pinion being profile ground on a 600 mm (24 in) machine. The formed wheel principle is being used the grinding wheel having been diamond trimmed from form plates so that it grinds the designed gap between two teeth.



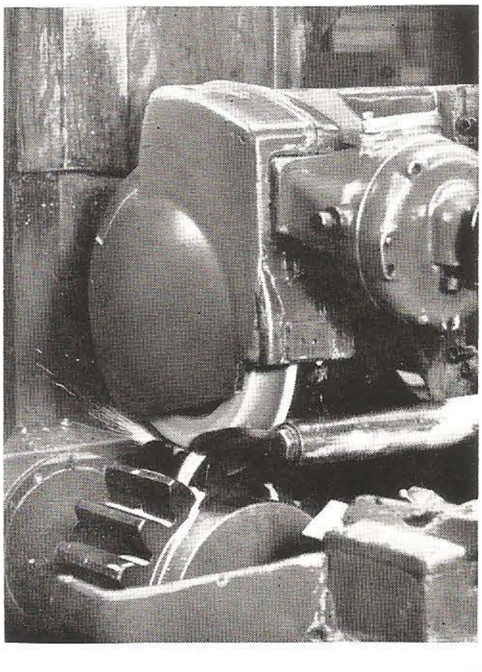


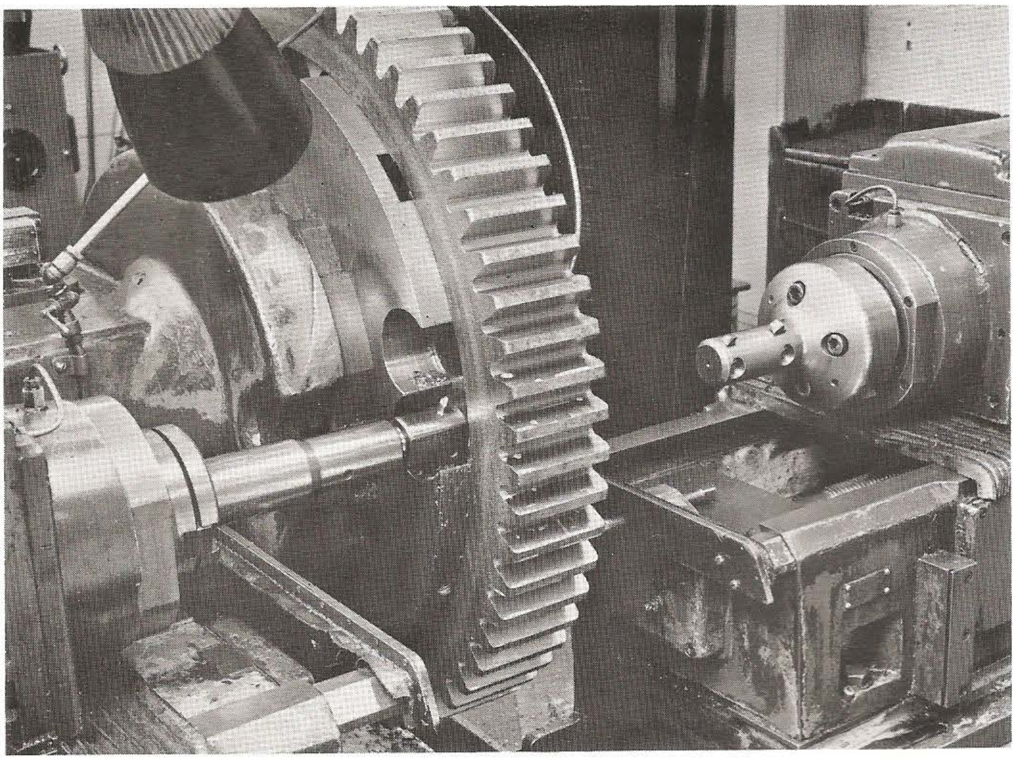
Quenching may be in oil or water according to the class of steel from which the gears are made. With carbon steels requiring water as the quenchant it is essential that this operation should be completed with great rapidity, and masking of the surfaces, as for example by the formation of steam or air pockets, must be avoided. This is accomplished by a spray ring which directs numerous jets of water onto the faces of the gearwheel or pinion undergoing treatment.

Tooth profile grinding

When heat treatment involves heating and quenching of the entire workpiece, distortion is inevitably introduced. Usually this must be rectified by grinding, and 1050 mm (42 in) and 600 mm (24 in) tooth grinding machines operating on the formed wheel principle are used. The grinding wheel is accurately trimmed to conform with the designed gap between two teeth and thus controls the form of adjacent tooth profiles. Accuracy of pitch is determined by the use of master indexing plates having the same number of divisions as the gearwheel or pinion which is being ground.

The deflections of the gear teeth and supporting shafts tend to concentrate the tooth loading towards the end nearer the driving motor. This is particularly so when, as in most traction applications, the pinion is overhung, that is without an outboard supporting bearing. It is possible to mitigate the effects of these conditions if the pinion teeth are crowned or ground with a slight taper towards the motor side, the taper approximating to a summation of the displacement angles resulting from the several predictable deflections. Specially adapted tooth grinding machines now reproduce the desired form of taper relief in a single operation where two were formerly necessary.

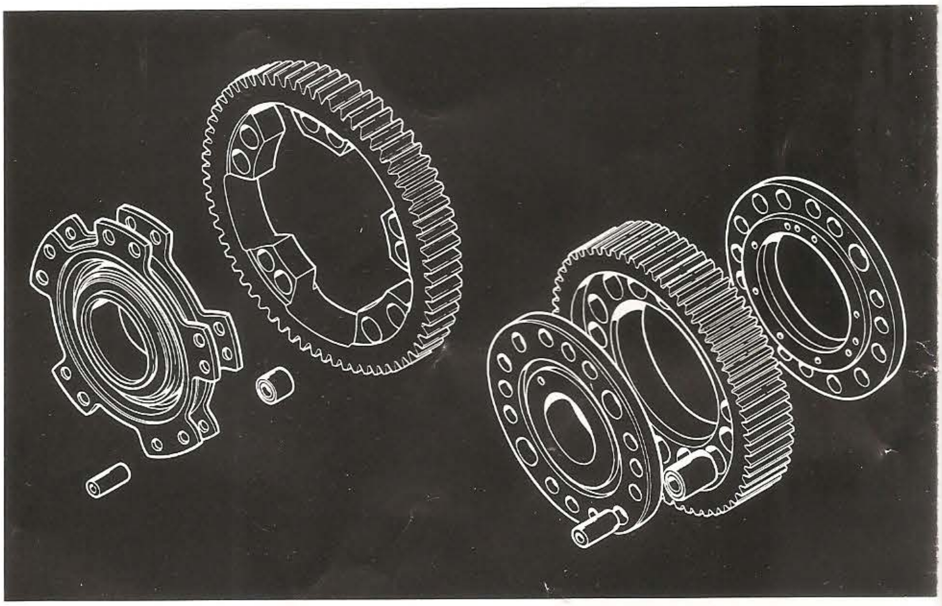


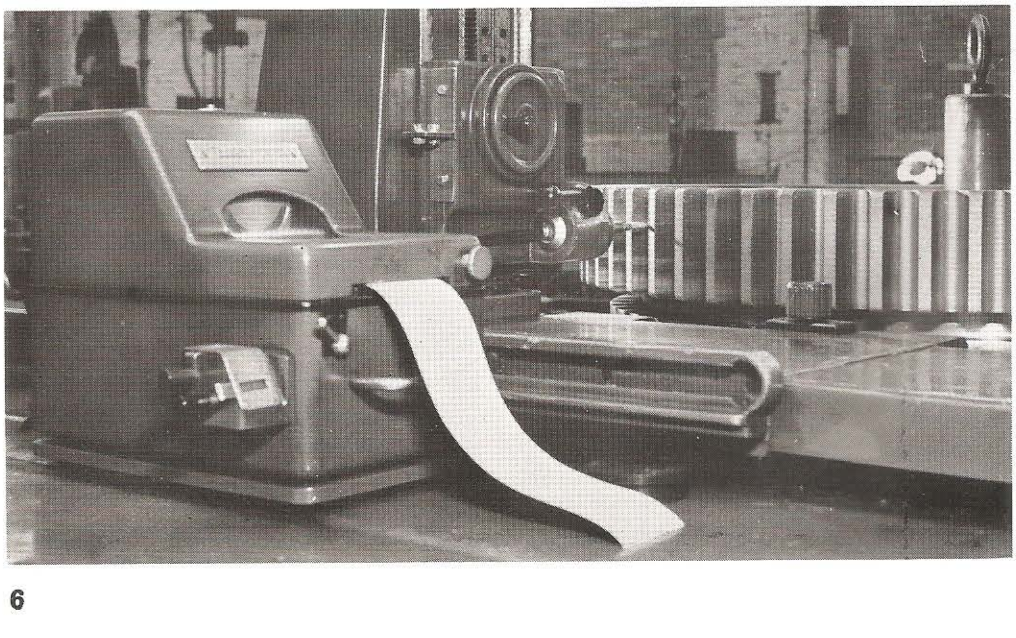


Final boring of holes for Silentbloc bushes in a resilient gearwheel rim. After being drilled the holes are successively rough and finish bored from each side.

Below left A typical continuous rim type resilient gearwheel with the side-plate removed to show the resilient units in the rim.

Below The construction of the lug-and-arm (left) and continuous rim types of resilient gearwheel.





Checking a gear tooth profile on a large involute measuring machine with a 1200 mm (48 in) diameter capacity. Deviations from the true involute profile can be magnified between 100 and 5000 times and permanently recorded on special paper.

Resilient gearwheel manufacture

Two designs of resilient gearwheel are manufactured. In one the rim and the centre portion are flame-cut from a single forging, leaving lugs on the inside of the rim and forming arms on the periphery of the centre portion. The rim is then machined to a T-section and the centre to a U-section, thus enabling the lugs to be located within the arms. Holes are machined in the lugs to accommodate the Silentbloc resilient bushes and in the arms to hold the driving pins which pass through the bushes. Each bush consists of three concentric sleeves assembled under pressure, the inner and outer sleeves being of steel and the middle one of rubber.

The other design, which is more complicated and expensive, was introduced to enable heavily loaded small gears to be fitted with an increased number of resilient bushes. It has a continuous rim of T-section supported between the flange of the centre and a side plate bolted to the centre. Driving pins and resilient bushes are fitted as before.

The drive is thus transmitted from the pinion to the gearwheel teeth and through the resilient bushes and driving pins to the gearwheel centre, which is mounted on the driving axle of the locomotive. Shock loads due to rail impacts transmitted in the reverse direction are cushioned by the resilient bushes.

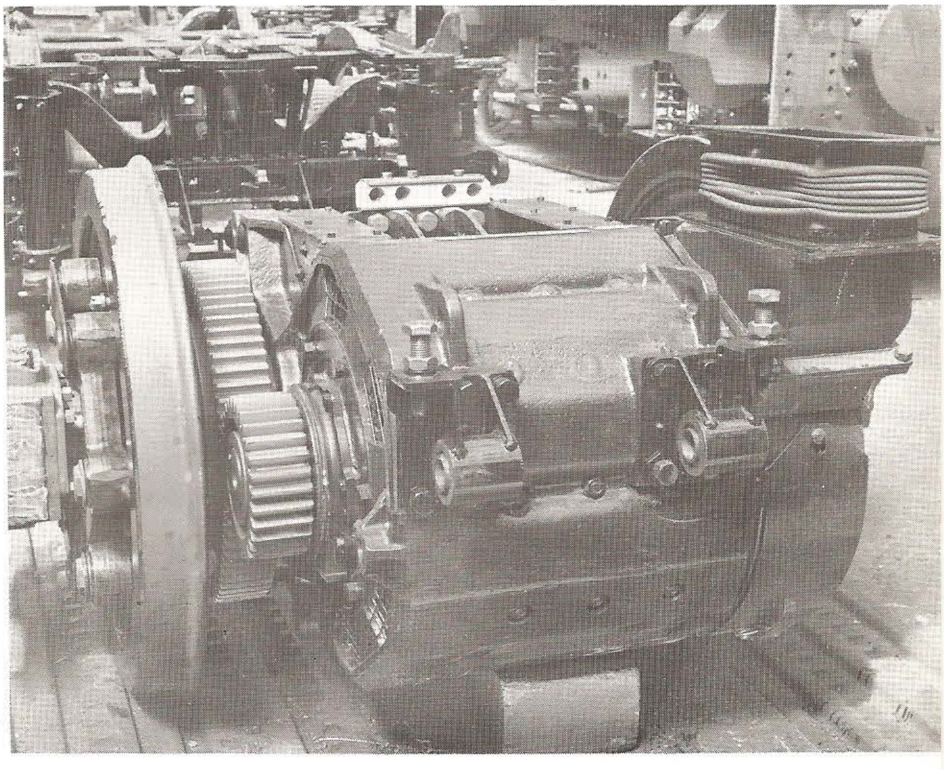
Inspection

Each gear is subjected to magnetic crack detection after heat treatment and again during final inspection. A specially designed profile testing machine is used to control the quality of output from the grinding machines. This machine has great rigidity, because it must support the heaviest gears without deflection. It is fitted with an electronic head and recorder, which provide varying degrees of error magnification. This machine and similar smaller ones are in constant use to test the products after both hobbing and grinding.

Recent attention to the techniques of hardness measurement have resulted in the production of instruments for checking the hardness of gears on the working tooth profiles and in the roots. This was impossible when hardness measurements were necessarily confined to those surfaces which were accessible to less specialised instruments.

The use of advanced instruments, together with inspection at every stage of manufacture, ensures a product of controlled quality capable of carrying out reliably the duties required of a traction gear.

Measuring the hardness of a gear tooth flank with a portable tester. The apparatus clamps over a suitable number of teeth and gives a direct Rockwell hardness reading at various positions on the working surfaces.



A motor and axle assembly, showing the straight spur reduction gearing. The unit is for a GEC 25kV a.c. locomotive for British Railways.

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