THE INTER-COUPLING OF ELECTRICALLY DRIVEN CANE KNIVES

By D. L. HUGHES

Introduction

The inter-coupling of two sets of electrically driven cane knives appears to offer the following attractive possibilities:

(*a*) An interchange of power between the two sets of knives which allows a lightly loaded set to assist the more heavily loaded set, thus reducing trip-outs.

(*b*) The combined inertia of both sets is available at all times to iron out peak loads.

Although this method of driving cane knives is mechanically sound, it presents problems on the electrical side.

The rigid coupling of induction motors is not sound electrical practice and in cases where it is essential, suitable control gear is installed to compensate for any difference in slip between motors. However, there are exceptions to the rule and one may be fortunate enough to "hit" on the right set of conditions, resulting in a successful drive. Before discussing the performance of coupled motors it would be as well to touch on the general characteristics of slip-ring motors.

(1) Slip increases in direct proportion to torque up to a point of approximately 200 per cent full load torque.

(2) Large motors very nearly attain synchronous speed on no load, the slip being of the order of .08 per cent.

(3) According to B.S. 2613: 1957 a tolerance of plus or minus 40 per cent of stated slip is allowed.

(4) Brush gear resistance depends on contact pressure and averages approximately 4 per cent of rotor phase resistance.

(5) For all practical purposes, speed variations, down to 10 per cent slip, are proportional to rotor circuit resistance, assuming constant load.

(6) Large motors in the range of 200 h.p. to 400 h.p. have full load slips of approximately 1½ per cent to 3 per cent depending on design.

Performance of Coupled Motors

In order that coupled motors of the same horse-power share the load equally they must satisfy two conditions:

(*a*) Both units must have the same full load slip.

(*b*) They must be coupled in the ratio of their synchronous speeds.

Consider the case of two 200 h.p. motors having identical speeds and stated slips of 2 per cent.

Condition (*b*) can easily be satisfied by coupling the motors either directly or through an accurately proportioned vee belt drive.

Condition (*a*) presents a problem, referring to characteristic (3) and assuming the worst condition the one motor would have an actual full load slip of 1.2 per cent while the other motor's actual full load slip would be 2.8 per cent. These motors would share the load in accordance with Fig. 1. At a total load of 400 h.p., motor 1 would be on overload delivering 280 h.p. while motor 2 would be running at 120 h.p. This illustrates an extreme condition and it must be borne in mind that any coupled drive will fall within the perfect and extreme conditions. Other factors which affect the full load slips of motors are the length of rotor cabling and the brush contact pressure.

The importance of an accurate coupling ratio cannot be overstressed because it is possible that a large inaccuracy in the wrong direction would cause one motor to be driven into a generating condition at no load. This state of affairs is not readily detected by means of the motor amp-meter and may exist, if the drive has horse-power to spare, without the operator being aware of it.

The coupling of motors of unequal horse-power and slip present a similar problem. Consider a 300 h.p., 2 per cent slip motor coupled to a 200 h.p. 3 per cent slip unit, the loading will be in accordance with Fig. 2. At a total load of 500 h.p. motor 1 would be operating on overload at 345 h.p. and motor 2 would be delivering 155 h.p.

Matching of Motors

Referring to the last example, the slip of the 300 h.p. motor must be increased to 3 per cent in order to match the 200 h.p. motor. This is achieved by adding resistance into the rotor circuit. The rotor resistance of this size of motor could well be .013 ohms. per phase which corresponds to a slip of 2 per cent, an additional .0195 ohm must be inserted to increase the slip to the desired value.

When dealing with the problem of matching motors, two obstacles present themselves.

(*a*) The low values of resistance are difficult to obtain.

(*b*) Most modern motors have short time rated brush gear and are fitted with slip-ring short-circuiting equipment. This makes it impossible to change the motor characteristics.

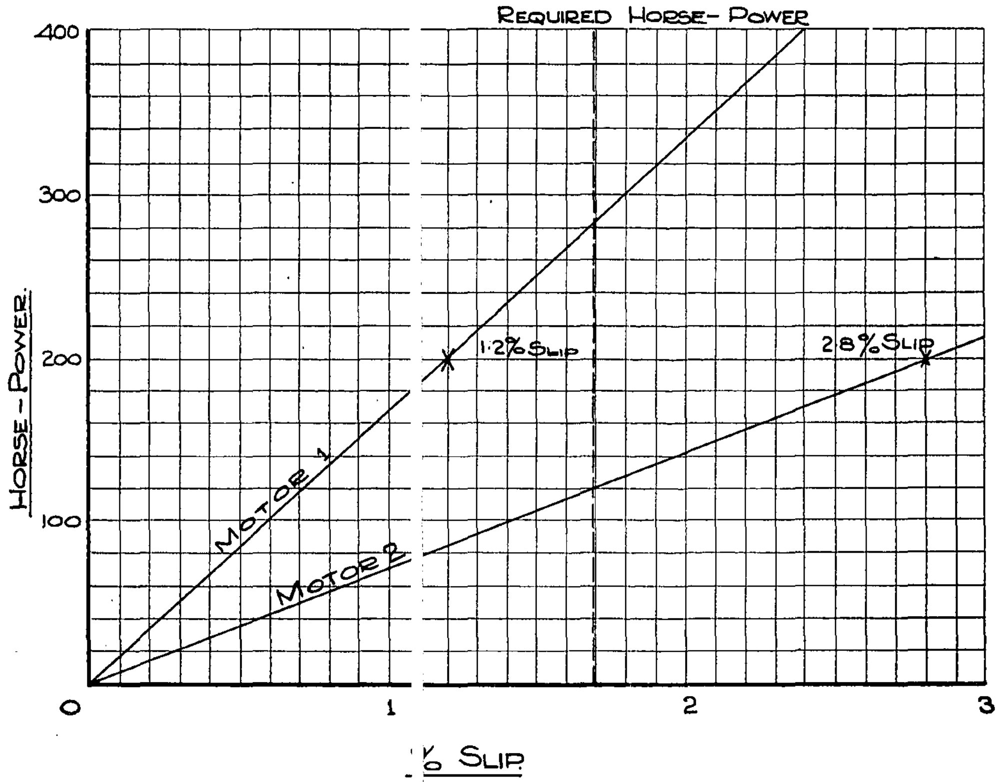
Required Horse-Power
Horse-Power
400
300
200
100
0
1
2
3
1·2% Slip
2·8% Slip
Motor 1
Motor 2
% Slip

Fig. 1

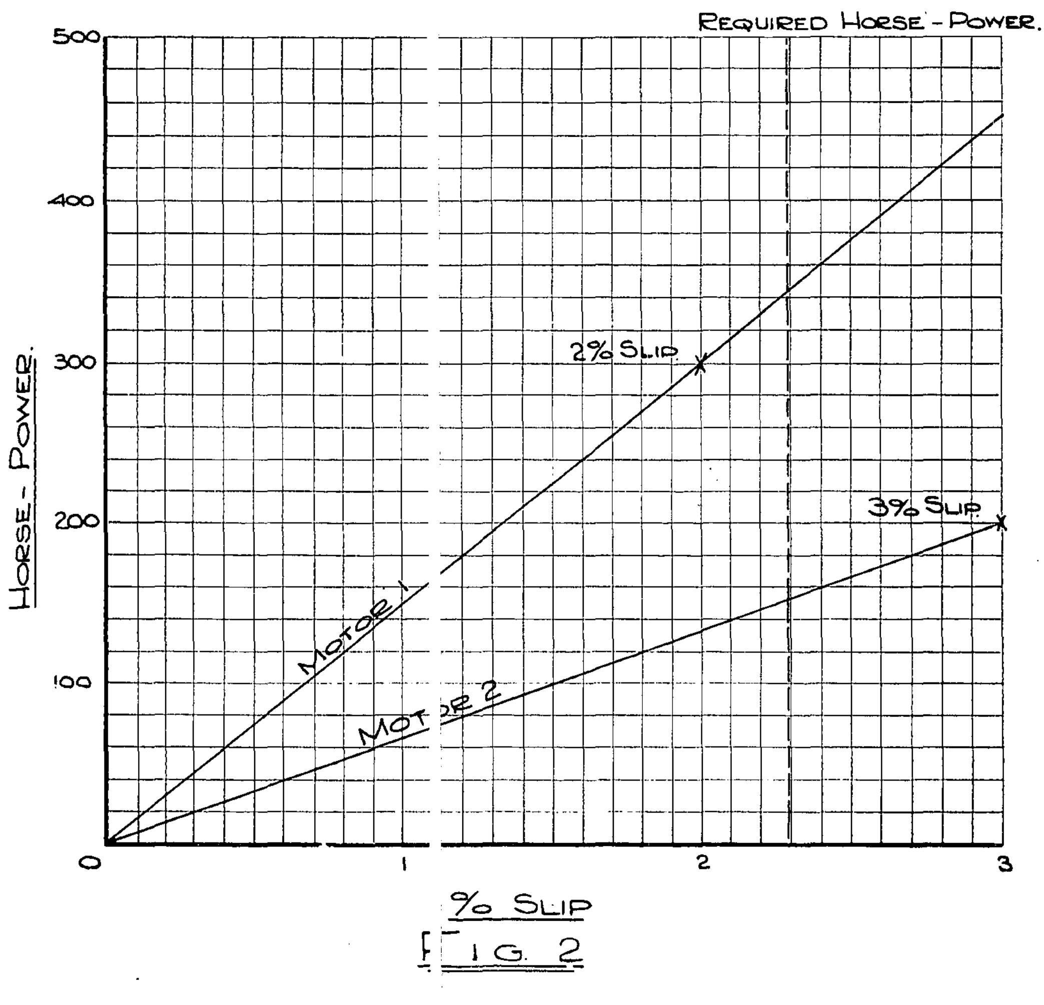
Required Horse-Power.
Horse-Power.
500
400
300
200
100
0
1
2
3
2% Slip
3% Slip
Motor 1
Motor 2
% Slip

Fig. 2

A crude method exists for overcoming the first obstacle. This is to add enough resistance into the rotor circuits of both motors to raise their full load slip to between 5 per cent and 10 per cent, these resistances are then adjusted by trial and error until the motors are matched. This method could waste approximately 28 kw. when applied to both motors in the above example, thus introducing an extra 7½ per cent loss into the system.

Conclusion

In view of the problems involved in coupling induction motors, it appears that the simplest method of obtaining trip free operation of cane knives would be to allow the knives to override the main carrier drive.

The coupling of the cane knives on each of the milling trains at Umfolozi has proved that the problems discussed above are very real indeed and can also prove to be costly.

Mr. Ashe stated that the problem of couping two sets of knives together originated from an idea which was put into practice in Australia and the investigation into this problem revealed certain difficulties which Mr. Hughes had mentioned in his paper. He asked if anybody who had been to Australia lately had seen the installation of two sets of knives coupled together with Vee belts or flat belts.

Mr. Gunn said that when he was in Australia he had seen two sets of cane knives coupled together but one was steam driven and it was coupled to an electrically driven set. This did not of course pose the same sort of problem.

Mr. Hulett, in the chair, brought up the subject of belt slip and creep on the pulleys and said as there was more belt going on to the pulley than came off due to the high tension on the one side as compared with the tension on the other side, this could account for as much as one or two per cent slip. He stated that in the curve shown in the paper no mention was made of this belt slip and he wondered if this would have an effect on the two sets of knives coupled together mechanically but driven electrically.

Mr. Hughes said he was not certain whether this belt slip would improve or deteriorate the position. He quoted a case of two motors of identical synchronous speeds with a one-to-one Vee belt coupling drive between them and with the same stated slip characteristics (see charactistic 3), which when put into use appeared to operate satisfactorily up to certain loads and then either shedded or broke the belts. It was found that by observing the ammeters during periods of heavy load that the one motor took the bulk of the load while the other motor was taking less than its share of the load, and therefore the Vee belts were overloaded. He then cited the case of another drive where the two motors had unequal slip characteristics and were coupled in the ratio of name plate full load speeds. By observing the ammeters he noticed that the one motor, which he referred to as the big motor, showed a small amperage, and as the system took load this amperage dropped and then rose very rapidly until the motor tripped. This he concluded was due to the fact that initially the big motor was being run as an induction generator and as load was applied to the system the small motor, which was doing the main driving at that stage, took the load and decreased in speed allowing the generation effect of the large motor to decrease, it then started taking the load. As this motor's slip characteristics were lower than those of the small motor, this big motor rapidly took most of the load and was eventually overloaded. From the above examples, it can be seen that the motor having the lower full load slip will take the most load.

Since belt slip increases with load it follows that the position should improve, but the drive behaved as though very little slip was taking place.

Mr. Hulett stated that it was apparent that if one endeavoured to couple two motors together one had to consider the synchronous speed and not the full load speed of the motors.

Mr. Hughes in answer to a question by Mr. Cargill said that it was difficult to couple one motor to another if they were not identical, and one had to be very careful with the rotor starters. It is well known that the amount of slip obtainable on the motor depends on the rotor resistance, which in turn depends on the condition of the short circuiting contacts and also, on liquid starters, how firmly home the rotor starter was put when it got into the run position. He recommended that a great deal of experimentation be done before the installation could be considered satisfactory. One method was to connect the rotors of both motors, through damping resistors, to a common starter. This can only be done if the motors have equal rotor voltages.

Mr. Cargill asked whether it would not be better to couple the motors mechanically but to include slip resistors in the individual circuits for each motor.

Mr. Hughes replied that in the long run it might be even better not to couple the two motors mechanically at all, because the cost of the pulleys and Vee belts was quite considerable and it would be better to use fly-wheels on the cane knife shafts, and thereafter if necessary, use slip resistors. However he considered that it would be better not to have the slip resistors, but to organise a cane carrier control which would reduce the speed of the cane carrier whenever the loading on the cane knife motors became excessive. This would prevent tripping of the motors.

The object of his paper was to demonstrate the pitfalls in such a combination of two motors and he considered his last suggestion was the best method of overcoming the problems involved.