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Typical Method of Connection of Electric Motor-gear Unit in the Frame of Universal Motor Gear Reducer

Characteristic conceptual solutions of connection of electric motor and gear unit, in the frame of universal motor gear reducer with helical gears, are analyzed in this paper. The aim of this analysis is to highlight the importance and benefits of particular solutions. It is known that today almost all major manufacturers of universal motor gear reducer use special (reducer) motors. Smaller manufacturers commonly use standard (IEC) motors, although large manufacturers, sometimes, also use IEC motors, especially when the customer request. The both of electric motors have certain advantages which manufacturers of motor reducer, with suitable construction solutions, want to use in order to achieve some benefits in the market.

Keywords: *connection, motor gear reducer, electric motor*

1. Introduction

Today, the professional literature says almost nothing about the problem of connection of electric motor and gear reducer in the frame of universal motor gear reducer. Maybe, it is because it is considered that this is not a special problem, which should devote some more attention, since "the motor is connected as it is the most preferable in particular case". However, that's not so.

Defining the method of connection is very important and interesting problem, which must be given great attention, not only because it directly affects the number of different electric motors and the total number of necessary gear, and thus the costs of production, especially on costs of motor and gears storage (as semi-finished and/or spare parts), but also because the method of connection strongly affects the speed of delivery of new or rebuilt reducer.

Today, when the delivery terms of universal gear reducers are very short (often only 72 hours) and when the costs of universal gear reducer are very low (due to very harsh competition), this issue must be given special attention.

The objective of this paper is to show possibilities and ways of reducing the number of different types of electric motors and gears, in the family of universal motor gear reducer. This is necessary because the costs of a number of different types of electric motors and gears, as well as the costs of their storage, are very high and represent a great burden for any small and medium manufacturers of gear reducers.

2. Description of the problem

As it is known, the universal motor gear reducer can be drive by special reducer electric motor or by standard IEC motor. What motor will be used depends on the attitude of the company manufacturer, as well as on specific customer requirements.

Large manufacturers usually use special motors, which are characterized by special flanges, special diameters of shaft end, stronger bearings and better sealing solution, so they have a number of advantages (simplier, cheaper and more compact construction, the possibility of achieving higher gear ratios, greater load capacity of motor shaft end and better tightness). Since these manufacturers are buying large quantities of such motors, they get them quickly and with cost of standard motor, so that their way of manufacture is fully payable. However, large manufacturers usually have their own electric motor factory, so that they have not a problem with buying special motors.

Small and medium manufacturers are forced to use standard IEC motors, mainly due to price and delivery time, and all advantages of special motor trying to compensate with suitable method of attachment motor with reducer. Since it is very difficult to compensate all special motor advantages, in practice we meet very different construction solutions of connection gear reducer with standard IEC motors, which are directly, or through an adapter for IEC motors, mounted on the housing of gear unit.

Large manufacturers, who use special motors, supply gear reducers with standard IEC motors especially when the customer's request. For example, when customers want to install motors, in the case they think they can do cheaper or faster service of their motors. Also, when gear units are exported in the country that have their own electric motor factory which is protected by its government by high taxes from foreign competition, and so customers do not want to buy a motor gear reducer, but gear unit with adapter for IEC motors. The adapters for IEC motors enable much simpler and safer mounting of IEC motors.

Delivery of special reducer electric motors is highly complicated because for each reducer size (shaft height) they have have specific dimensions of free end of the shaft and specific size of flanges (usually 4 to 6), but they undoubtedly provide multiple advantages of motor gear reducers.

Application of the standard IEC electric motors, which are directly (without an adapter for IEC motors) attached to the housing, requires special partition plate

and usually a special ring and shaft seal (to ensure tightness). High gear ratios on the first gear pair can not be achieved by application of the standard electric motor. So the practice is that a bushing is set on the free end of motor shaft and a relatively small pinions are impressed in it, which allows a large gear ratio.

However, in this case the pinion has the big overhang, which significantly reduce its load capacity. Therefore, motor shafts are being shortened at certain sizes of electric motors, but then it can no longer speak of standard IEC motors. Shortening of shafts is sometimes performed because of lack of space for the installation of large motors.

In order to avoid a problem that occurs because it is not possible to achieve high gear ratio on the first pairs, some manufacturers do not produce single-stage gear reducer. It doesn't represent a major problem for them considering that the one-stage gear reducer is relatively little searched on the market and particularly due to the fact that higher values of gear ratio of single-stage reducer can cover a smaller ratio of two-stage gear unit, but at some higher price.

In addition, a limited number of first gear pairs requires a different combination of gear pairs, usually less pinions, small and inexpensive gears, but more larger and expensive gears. This makes production and gears storage more expensive, but significantly simplifies the purchase and storage of electric motors, which price and production costs in overall costs of motor gear reducers are quite large. It is a big problem with this solution because of the clumsy construction of the motor gear reducer, especially when stronger motors are used which are mounted to the reducer housing.

3. Description of ways of solving problems

A special reducer motors have multiple advantages, but require, for the same motor power, manufacturing, and storage of a large number of different motor types (for smaller producers who don't have their own motor factory). This really complicates the production, so small and medium gear reducer manufacturers use them rarely. They believe that application of standard IEC motors is the simplest solution.

Only direct connection of IEC motors and reducer will be analysed in this paper, since application of adapters for IEC motors represents a particular solution usually used by manufacturers which basic program is producing special reducer motors. The application of IEC motors can be implemented in two ways.

3.1. Solution with Pinion Placed on a Bushing

The first solution is when a family of universal motor gear reducers can consist of single-stage, two-stage and multistage gear reducer. Connection of motor and gear reducer is done by using appropriate partition plate and pinion is placed on a bushing and attached on the shaft of electric motor. In this case, there are several

partition plates (they can be with more complex form) but smaller number of motors, and there are several bushings but less different pinions. Company HORZ produce reducers with this typical concepts solution.

In this case, adopted conceptual solution of the universal gear unit has certain impact on the required number of gear pairs. Namely, the universal gear reducer can be produced in various ways, as single-, two-, three-stage and multi-stage gear reducer. Single-stage reducers are usually made in single-gear housing. Two-stage reducer could be produced in a special housing for two-stage gear pairs, or in the universal housing for two- and three-stage gear pairs. Three-stage reducer could be produced in a special housing for three-stage gear pairs, or in the universal housing for two- and three-stage gear pairs, or in a combination of two housings of two- and single-stage gear unit, etc.

Some manufacturers do not produce single-stage gear reducer, because they are rarely required on the market. Although there are those manufacturers who produce single-stage reducers with a big gear ratio which value overlaps with the area of two-stage reducer, and thus, they can in a certain segment of gear ratio successfully compete with two-stage reducers. Of course, there are those manufacturers who do not produce four- and multi-stage gear reducer. However, regardless of the construction, every multi-stage reducer has the first gear pair, second gear pair, etc, so the number of gears a little depends on the concept, but a lot of the largest size of gear ratio, ie. the nominal torque of gear pair. If the gear ratio is high, the offering of different gear ratio is bigger, which is good and justified, but unfortunately it causes a bigger number of necessary gears.

Construction of gear reducer has great influence on the number of necessary gear. The number of gear pairs, for the same shaft height of the housing, really depends on the space available for accommodation of gears. Therefore, the wider housings are now used, because they enable larger shaft distances for the same mounting dimensions of the housing. Then, the way of mounting the pinion on electric motor shaft has also great influence on the number of necessary gear.

Today, the pinions are often impressed in the shaft of electric motor in order to obtain high gear ratio, or they are placed on a special bushings mounted on electric motor shaft.

The number of necessary gear also depends on available technology. Higher gear ratio can be achieved with modern technology, so that the pinions can have teeth number less than 10, also concept of paralel gear unit is abandoned, high- and slow running gear chamber is opened to put a big gears in it, etc.

Very important task, regardless of whether such manufacturer produces only single gears or reducers, is defining the size of gear ratios (Fig.1) and number of gear pairs (Fig.2-a) of single-stage gear pair.

The values of gear ratios are typically adopt from the standard line R10, because in the case of application of line R20 there would be too many first gear pair, especially the pinion, which is made with various openings (that could be set to different sizes of electric motors).

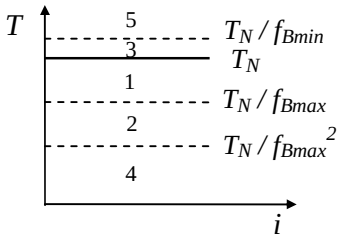

Figure 1. Schematic review of application field of universal gear reducer according to torque values: 1 - the main area, 2 – the additional area, 3 - critical area (used only for short drives), 4 - the area where the reducer is oversized and 5 - critical area where breakdown of the reducer happens immediately geometry.

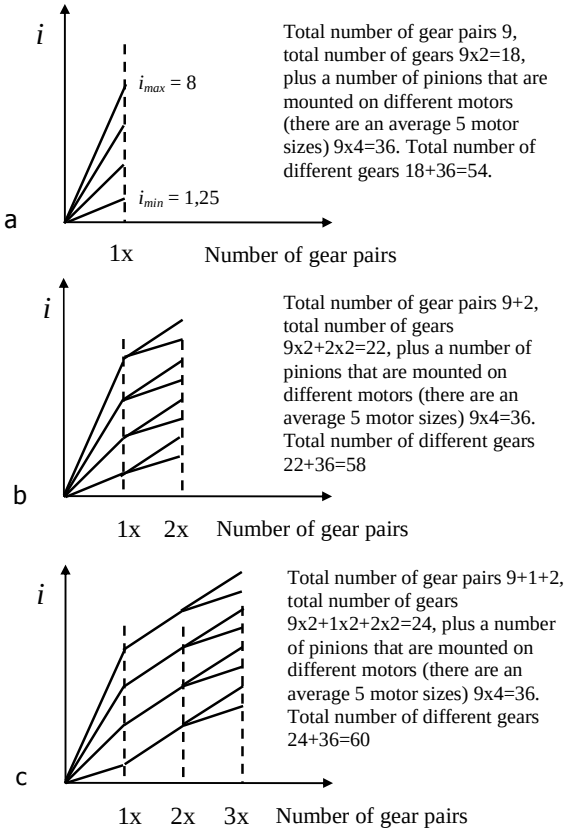

Figure 2. Schematic review of gear ratio distribution for a- the first gear pair, b- two-stage gear reducer and c- three-stage gear reducer.

The greatest value of the gear ratio is adopted depending on the available technology (pinion with the smallest teeth number) and adopted way for mounting the pinion on the electric motor shaft. Recently the highest values of gear ratio of the first gear pair have been between 6.3 and 7.1 and today very often 8 and even up to 12.5 (Lenze). What the largest gear ratio will be adopted depends on the adopted gearing concept (large gear ratio and a small load capacity or vice versa). However, as it has already been said, it is quite common that two sets of gears are offered for the same shaft height of the housing.

For two and multistage reducer, gear ratio is offered in a row R20. These gear ratios for two-stage gear reducer are usually obtained by a combination of two second gear pairs (Fig.2-b). Gear ratios for three-stage reducer are obtained by a combination of one second and two third gear pairs (Fig.2-c), but it can also be differently.

Because of this solution, in some cases, the motor shaft is being shortened and then it is not standard IEC motor, so this concept will not be further considered.

3.2. Solution with Pinion Mounted Directly on a Motor Shaft

The other solution, when IEC motors are used, is that single-stage gear reducers are not used, but only two-stage and multi-stage reducers are produced and the pinion is placed directly onto the shaft of electric motor. In order to achieve higher gear ratio with this solution, the practice is to increase the axis distance on the first gear pair, and thus larger gear wheel can be applied. Since in this concept single-stage reducers are not used, diameter of gear wheel is not limited by shaft height as on other solutions. Of course, it affects a certain increase in production costs (due to larger gear wheels), but their way of production is still fully payable. Characteristic representative of this solution is the company ROSSI.

In this case, the values of gear ratio (Fig.3-a) are a little different (usually there are not high gear ratio for big powers in the frame of same shaft height) and the number of first gear pairs is reduced (because small pinions can not be mounted on the shaft ends of the larger electric motors for direct connection of pinion and the end of the motor shaft).

For two- and multistage reducer, gear ratio is offered in a row R20. These gear ratios for two-stage gear reducer are usually obtained by a combination of two second gear pairs (Fig.3-b). Gear ratios for three-stage reducer are obtained by a combination of one second and two third gear pairs (Fig.3-c), but it can also be differently.

Determining the number of necessary pinions, with various openings, for the same gear ratio, is done according to the diagram shown in Fig.4. Determining procedure depends on the size of nominal torque and, certainly, of the applied standard IEC electric motor. Based on the power chart (Fig.4), electric motors are defined which would be justified to connect with such reducer, and also, openings in pinions and required partition plate diameters are specified.

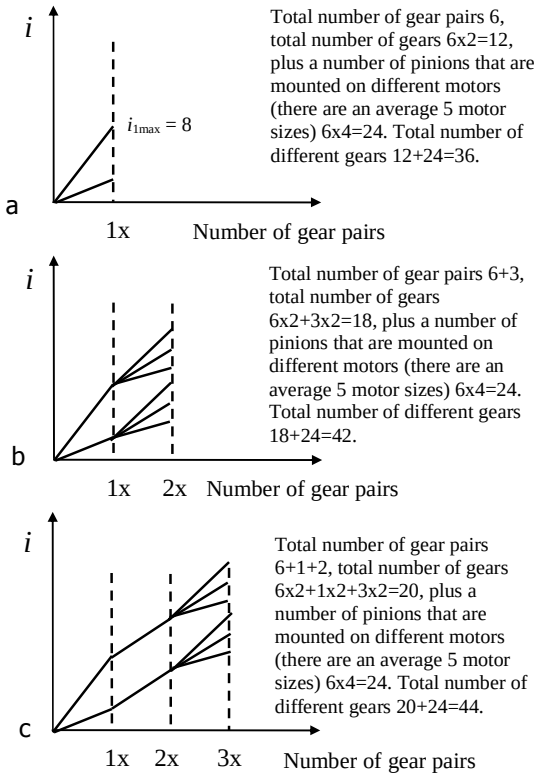

Figure 3. Schematic review of gear ratio distribution for a- the first gear pair, b- two-stage gear reducer and c- three-stage gear reducer when IEC motors are used.

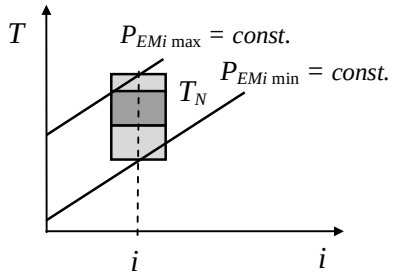

Figure 4. Schematic review of nominal torque changes depending on the size of reducer gear ratio (in logarithmic coordinates).

Only quadripolar (three phase asynchronous) motors are considered in defining required motor power, because they have the best starting characteristics and are the easiest and fastest purchase. Different motors can be also delivered as the motor gear drive, but usually at a higher price.

Some manufacturers of gear reducer produce the output pair with different direction of helical angle, for two- and three-stage reducer, in order to decrease axial force on the gear shaft of output pair, which strongly affects the total number of gears. The other producers use a stronger bearing (cylindrical roller bearings of the same sizes), which can accept a much larger axial force and thus avoid a large number of gears, which is certainly more favorable solution.

Nominal torque value for each size of the gear ratio is defined separately depending on the load capacity of gears, keys, shafts, bearings and housings. Since there is no standard in this field and if it is possible from the standpoint of strength, it is allowed to shift torque values up and down from the projected values. The final definition of torque value must take into account the characteristics of competitive solutions, in order to provide mutual replaceability of gear reducers.

Based on the diagram (Fig.5), certain gear pairs of three-stage reducer are differently loaded, which can make following conclusions: if two-stage reducer is manufactured in the special housing for two-stage reducer, and three-stage reducer is manufactured by combination of two- and single-stage reducer, it follows that the first smaller size of single-stage reducer will be used for three-stage unit, which usually does not represent any problem. The other case is when the same housing is used for manufacturing two- and three-stage gear reducer (as most the case), ie. when the same output shaft and gear wheel are used for two- and three-stage unit in order to rationalize its structure. These output shaft and gear will be used irrationally in two-stage gear unit (if the first couples are kept in the three-stage reducer, dashed line in Fig.5), or stronger first pairs must be used in two-stage unit (which is the most common case), so that in three-stage reducer the first pairs must be used from the first smaller two-stage unit.

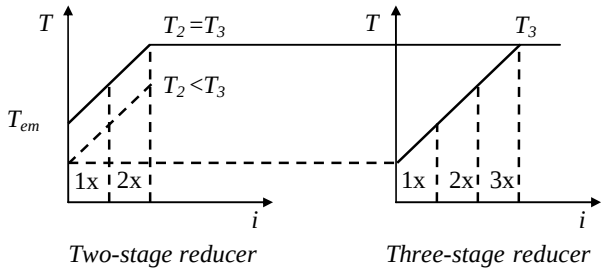

Figure 5. Schematic review of necessary load capacity of gear reducer for particular gear ratios of reducer.

Some manufacturers define the same load capacity for two- and three-stage gear unit. The others offer smaller load capacity of two-stage reducer, despite the fact it could be heavier loaded. It is because the output pairs in two-stage unit rotate faster and thus bearings and gears do not allow such heavy load, but also because in all stages the same size of electric motor and same pinion is used, ie. the opening diameters in the pinions are the same (Fig.6). This is certainly justified solution and it should be applied.

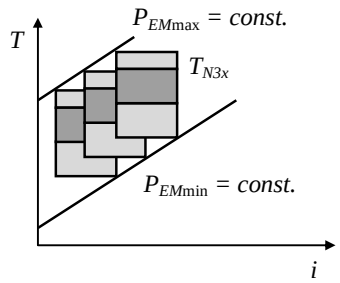

Figure 6. Schematic review of nominal torque and gear ratio areas of gear reducer covered by one-, two- and three-stage units for the same size of universal gear reducer.

Some manufacturers mark priority ratio, which can immediately offer, in order to reduce the number of pinions and electric motors that need to keep in stock (these values are usually bold in catalogues), while for the other ratios (revolution number) they offer longer delivery time. This offering way could be the solution for other manufacturers of gear reducers.

4. Conclusion

If series of universal motor gear reducers are reduced, small and medium manufacturers of motor reducer (which using the standard IEC motors) obtain some advantage in the market according to manufacturers who use special motors and do not have their own factory. It is because they need to keep in stock a large number of different motors and gears, in order to provide short delivery of their gear reducers. Based on this analysis, small and medium manufacturers who use a special reducer motors will certainly be able to achieve a particular advantage in the market by small constructive modifying their reducers and starting to use IEC motors (with direct pinion placing on to the shaft of IEC motor), with a little rise in the production cost (due to the increased distance of the first axis distance).

Special marking of priority gear ratios and corresponding gears and motors is particularly interesting possibility from the standpoint of "reducing" the required

number of gears and electric motors. With this solution, the apparent reducing of number of different gears (motors) that manufacturer need to keep in stock is achieved (especially in the service - repair centers, which are usually located near large markets). This is favorable for faster delivery and easier and faster service (or repair) of gear reducers.

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