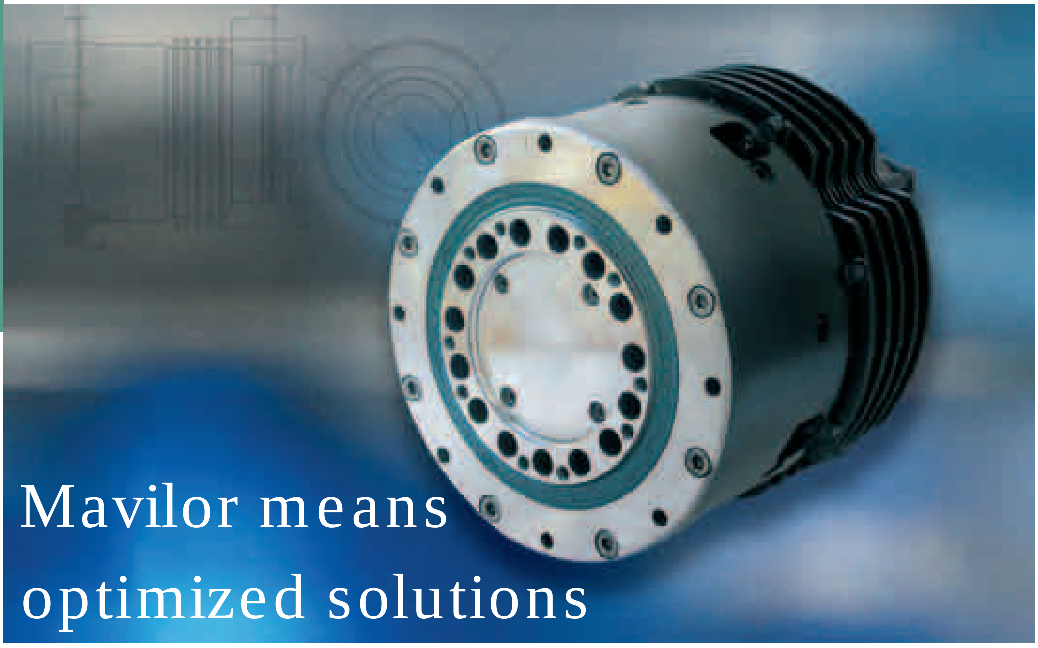
MAVILOR
INFRANOR GROUP COMPANY
EXPRESS

CONTENTS

January 2005

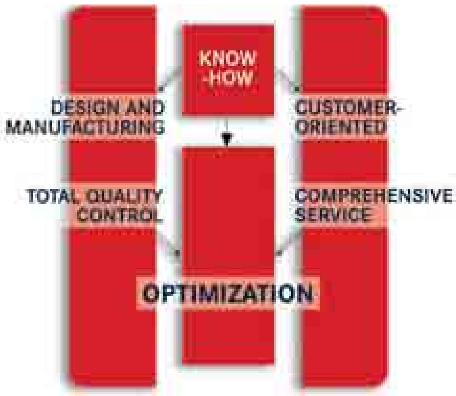
ACTUATOR COMPAC
Servo Brushless Motor



ACTUATOR

The Actuator is the ideal combination which uses exclusive non-cogging MAVILOR's brushless motor technology with the unique reduction system that the REDUNOR gearbox system offers.

LOW BACKLASH
HIGH TORQUE & SPEED
WIDE RANGE OF REDUCTION



INTRODUCTION

In this edition of Mavilor Express we offer readers an extract of an article contributed by Dr. J.C. Compter about choosing a motor. The article focuses on analysis of the applicability of specific motors based on several criteria. It is a summary that we will be following up with the continuation of the article in the next edition of Mavilor Express.

Following this we feature an application of Mavilor Motors in Turkey done by the company Adim Otomasyon with the cooperation of our distributor Daye Machine Tools Ltd. Co. This is an X-Y table which is used in the manufacture of three dimensional objects.

And lastly, you will find a graphic of an application developed by Infranor Germany for their client, Wenzel Prazision GmbH. Over the past 30 years WENZEL has become one of the world's leading manufacturers of Coordinate Measuring Machines. The model featured here uses a MSS-4 Mavilor Servomotor for axis movement.
Thanks, the Mavilor Team.

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Choosing a motor.

by Dr. J.C. Compter

This article is a short extract of "choosing a motors" the rest of the article will be published in the next issue of Mavilor Express.

The process of choosing a motor is preceded by an analysis of the load ; this analysis must at least provide an answer to :

1) maximum speed
2) maximum torque required
3) the period of time of the motor torque
4) in combination with a transmission 1 :n Y/N

A standpoint must also be taken as regards :

1) main emphasis on operational reliability or performance
2) is the cost price important and if so, what then is the budget for the complete drive, consisting of the transducers, amplifier, motor and any transmission ?
3) standardisation
4) preference for a brand
5) space restrictions
6) requirements of motor temperature and the environment
7) weight restrictions
8) preference for a particular type of servomotor
9) a protection class desirable (splashproof, explosion-proof…)
10) reliability and life
11) imbalance vibrations, cogging, noise, electromagnetic radiation
12) requirements of the bearings
13) mounting on a frame by means of a flange, screw thread, etc.
14) method of connection, integral temperature sensor.

These points are not listed in any particular order ; their priority is usually determined by the application.

Following this preparatory work, we can look at different motors. Analysing the aplicability of a motor is generally a time-consuming process ; a number of suppliers have therefore developed software that can present realistic choices on the basis of a database and a questionnaire. The Motsel program is one such example. We shall now consider the criteria employed in software of this kind.

Torque, speed and the area of activity

As we have previously indicated, a motor is characterised by a torque-speed relationship (see Fig. 6.1). Remember that this relationship goes with a particular motor temperature, because the motor resistance and K-factor are temperature-dependent.

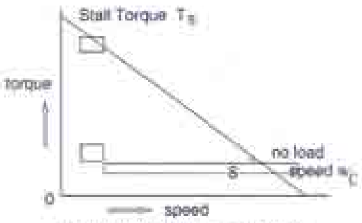

Fig. 6.1 The torque-speed curve

The purpose of a motor is the delivery of mechanical power ; this power is given by :

$$P_{mech} = \omega . T = \omega . S(\omega_0 - \omega) = S(\omega . \omega_0 - \omega^2)$$

With

$$\frac{d\,P_{mech}}{d\,\omega} = 0$$

it is easy to establish that the maximum power Popt is delivered at :

$$\omega = \frac{\omega_0}{2}$$

and then is equal to :

$$P_{opt} = \frac{\omega_0}{2} . \frac{T_s}{2} = \frac{U}{2K} . \frac{U.K}{2R} = \frac{U^2}{4R}$$

Fig. 6.2 shows the curve of the output power as a function of the torque. The interpretation of this figure requires some explanation. Let´s say that the motor sets itself to the speed indicated under the

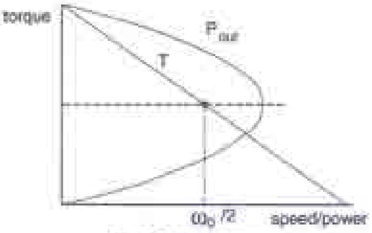

Fig. 6.2 Output power

influence of the load. A certain motor torque goes with it (readable via the horizontal line). Finally, an output power Pout goes with this torque.

The efficiency of the drive is also a factor. If we include both a static friction Tf and a viscous friction Td =ωd, then we have :

$$\eta=\frac{(T-T_f-T_d).\omega}{U.I}$$

Following substitution we have :

$$\eta=(T-T_d-T_f).(\frac{1}{T}-\frac{1}{T_s}).$$

with Ts the stall torque.

As shown in Fig. 6.3, a point on the torque-speed curve T-n can therefore be indicated where the motor has maximum efficiency. By way of substitutions and differentiation of the efficiency to the torque T we can prove that a maximum efficiency Pshaft / Pin is obtained at :

and

$$T_{ec}=\frac{1}{S}\sqrt{T_s.(d.T_s+S.T_f).(d+S)}-T_f-d.\omega_0 \text{ and}$$

$$\omega=\omega_0-\frac{1}{S}\sqrt{\frac{T_s.(d.T_s+S.T_f)}{d+S}}$$

In choosing a motor we have to find a compromise between efficiency and output power. Giving priority to efficiency leads to a larger motor. In Fig. 6.3 a good compromise can usually be found inside the range given by the two points marked on the maximum torque-speed curve and the origin.

In a servo system however the motor voltage is not fixed ; the controller will supply the motor with a varying voltage by way of the output amplifier. Fig. 6.4 shows along which lines the points Popt and ηopt move.

Given the aforementioned compromise, the motor working point will preferably lie between the line of maximum efficiency and output in Fig. 6.4.

Combining Fig. 6.4 with Fig. 3.12 gives us Fig. 6.5. SOA stands for Safe Operation Area, preferably operate betweeen the Popt and ηopt line to combine an acceptable efficiency and a high output power. Additionally one has to reconsider the motor chosen when the worst case operation point can be found under the T-ω line belonging to 0.5 Unom (motor under loading). Within Philips on also prevents to exceed momentarily the T25-line ; this is based on a questionable carefulness ; the more one knows concerning the application and motor one can shift this limitation upwards. Finally remains the area with a dashed contour as preferred operation area.

Steepness

Here we define the steepness of a motor as K*K/R. This is one of the most important motor parameters, because it can be found in the equations :

- dissipation

$$P_{diss}=\frac{T_{max}^2}{S}$$

- mechanical time constant

$$\tau_m=\frac{J}{S}$$

- speed versus torque

$$T=S.(\omega_0-\omega)$$

- maximum continuous torque

$$T_{100}=\sqrt{Q_{max}\cdot S_{\theta_{max}}}$$

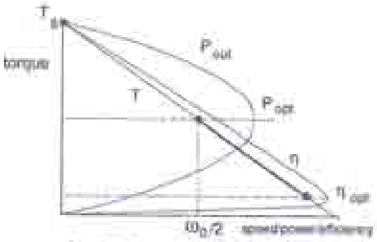

Fig. 6.3 Output power and efficiency

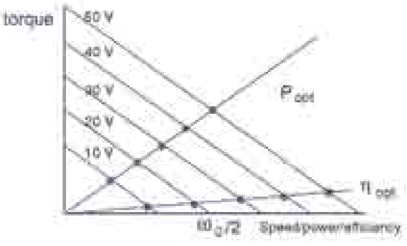

Fig. 6.4 Influence of motor voltage

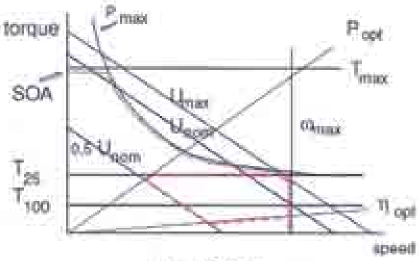

Fig. 6.5 SOA

*the position of maximum efficiency

$$\omega = \omega_0 - \frac{1}{S}\sqrt{\frac{T_s.(d.T_s + S.T_f)}{d+S}}$$

When the terminals of a motor are short circuited one will notice that the motor acts as a viscous brake with S as the ratio between the torque and radial speed (prove this).

For servo technology a high value of S is attractive, because it leads to less dissipation at a given torque, a lower mechanical time constant, a higher permissible torque.

Load Cases

Static Load

If the servo loop has the task of driving load at an almost constant torque and speed (a static load), it is easy to show in fig. 6.4 where the working point of the motor is. Verification of the maximum permissible value of the torque and the speed is followed by a check on Trms, which must be less than T100. And if the point Trms / nominal speed is also between the lines of Popt and çopt, then we have a suitable motor.

If this is not the case, a transmission can provide a solution. Let´s say that we have the working point 1 in Fig. 6.6. For the mechanical power we have Pout=ùload.Tload.A transmission (without losses) with a transmission ratio i leads to Tmotor= ùload/i. The result is that, depending on the value of i, a different point on the curvein Fig. 6.6 can be used.

With static loads we have complete freedom to choolse such a transmission ratio that the efficiency for example is at a maximum or it is possible for example to suffice with a(n) (available) supply voltage.

Dynamic Load

Contrasting with this static load is the pure dynamic load, which is characterised by a load torque that is only used for the constant acceleration and deceleration of the load and motor. This means that the moments of inertia of load and motor in combination with the desired accelerations determine the motor torque required. With a transmission ratio i, the torque required is as follows :

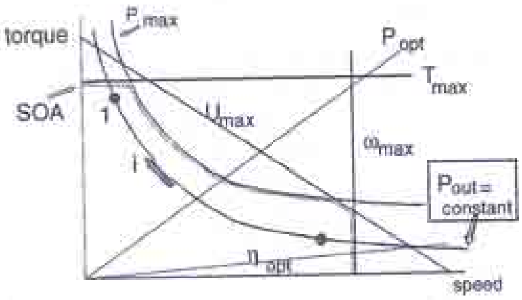

Fig. 6.6 Influence of transmission ratio

The transmission ratio i largely determines what torque the motor must deliver. Since the cost price of a motor and the maximum torque are closely linked, a low torque is preferable.

The question now is what transmission ratio i must be chosen in order that a minimum torque T suffices. Depending on the load, the curve of the motor torque as a function of the transmission ratio can be a flat or a strong minimum (see Fig. 6.7). Differentiation of the above equation to ùmotor leads to the condition that is known as ¨INERTIAL MATCH¨.

With i =ωmotor / ωmotor

$$T = J_{motor}.\dot{\omega}_{motor} + i.J_{load}.\dot{\omega}_{load} = J_{motor}.\frac{\dot{\omega}_{load}}{i} + i.J_{load}.\dot{\omega}_{load}$$

gives us :

$$\frac{dT}{di} = -\frac{J_{motor}.\dot{\omega}_{load}}{i^2} + J_{load}.\dot{\omega}_{load} = 0$$

$$i = \sqrt{\frac{J_{motor}}{J_{load}}}$$

The fact that there is a minimum can be explained as follows : if an extremely large transmission ratio i is chosen, the term in equation (105) with the moment of intertia of the load will predominate and the torque will grow proportionately to i. This leads to an initial conclusion : reduce i. If this were to go too far, then the term in the formula with the motor moment of inertia would predominate. The reason is that with a low i the angular velocity of the motor is high, so that a lot of energy has to be expended on the acceleration / deceleration of the motor.

The curve of the motor torque as a fuction of i is an hyperbola (: l / i) at low values of i, which leads to the conclusion : increase i. Result_ somewhere there is an optimum.

Show that the motor sees as load torque T :

$$T = J_{tot} . \dot{\omega} = (J_{motor} + i^2 . J_{load}) . \dot{\omega}$$

The procedure to follow to see whether a particular motor is suitable for this dynamic load :

1) Determine the transmission ratio that goes with the ¨Inertial Match¨.

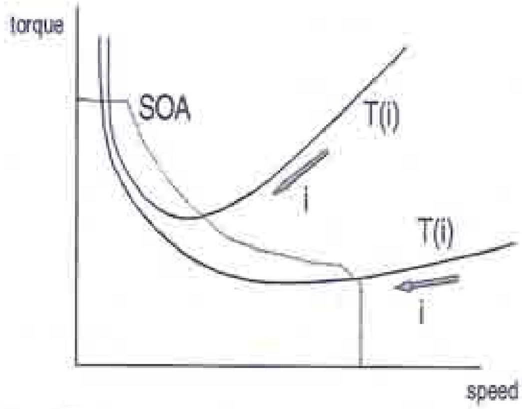

Fig. 6.7 The curve of the motor torque and speed as a function of the transmission ratio i for two cases

2) Process the moment of inertia of a suitable transmission (seen from the motor side) in the total moment of inertia and over one or more strokes see whether the ¨Inertial Match¨can be achieved in combination with the available transmissions.
3) After 2) are all the working points of the motor inside the SOA ? (maximum torque, maximum speed ; this point is also called ¨Worst-case operation point¨).
4) Is Trms less than T100? Since T100 falls at elevated speeds with electronically commutated motors, a safe design is obtained if the value of T100 at the maximum speed occurring in the design is compared with Trms.

It is recommended that the curve of the motor torque be drawn as a function of the transmission ratio, because depending on motor moment of inertia, mechanical time constant and required acceleration for example there can be a flat area around the optimum.

Analysis of the open loop transfer function of a servo system shows that an advantage can be obtained by the selection of a certain ratio between the moments of inertia of the motor and the load plus retardation. Choosing equal ratio or simply deliberately a relatively light motor also depends on the position of the sensors. The dissertation by Mr. Groenguis (TU Eindhoven) goes into this more deeply.

Static / Dynamic Hybrid

In a similar fashion to the one described above a method can be worked out that describes hybrids. It requires a good description of the load. Since the quantity of calculations is considerable, the use of a numerical tool is preferable, because a choice of motor and transmission ratio must be determined iteratively. The value of i that delivers a munimum torque is affected by the friction and damping present, so the ¨inertial match¨ is not always the best solution.

ADIM OTOMASYON
Turkey- Istanbul application

With cooperation of our Distributor in Istanbul DAYE MACHINE Ltd. Company. This Adim Otomasyon application consists of two BLT-74 + one BLT 72 + two BLT-72 with break and 4 Mesa drives MSD1-MA-3006E

Net working area : 3000*2000*200 mm

Working speed : 35 m/dak. Travelling speed

Mechanical system : 20*20 mm rack-pinion X1-X2 and Y axis
: 16*10 ball screw on the z axis
: Linear guideway 25 mm for X1 and X2
: Linear guideway 20 mm.for Y Z axis

Router working table : Aluminum slotted vacuum ready table

Motor system : 2,7 Nm nominal torque Servo Motor.X1-X2 Y axis
: Z axis 1,9 Nm Servo Motor

Machine Body : Fully metallic construction , box type profile.

Control System : Motion board . 4 axis servo board NEE Controls with integrated
: MHP1 Type handpad.

PC Software : WinAMC HMI operator interface. For CAD/CAM program uses
: that it has as output file DXF, HPGL or G Code controller.

Bit cooling : Trico model mist coolant system

Accuracy : +/- 20 mikron

Dust Collection system : 0,75 kw motor power and dust collection head with complete
: unit .

INFRANOR GmbH Application

Client: Wenzel Präzision GmbH

One of the world's leading manufacturers of Coordinate Measuring Machines

MSS-4 MAVILOR SERVOMOTOR for movement of the axis.

Bridge Type CMM (Coordinate Measuring Machine)

Wenzel Präzision GmbH

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