8. Bearing lubrication

Safe operating and long rating life of bearings depend on the lubricant type and quality and on the lubrication method. Bearing lubrication is used for certain purposes, such as:

- to reduce friction between rolling elements and raceway, rolling elements and cage, cage and guiding ribs of rings during operation;
- to ensure anticorrosive protection of bearings;
- to reduce noise in bearing within certain limits;
- to distribute heat uniformly in contact areas and to remove it outside through lubricant circulation.

Lubricants for bearing lubrication should satisfy the following conditions:

- they should have physical and chemical stability;
- foreign mechanical substances (abrasive, metallic substances etc.) are not admitted in lubricant;
- they should have a minimal coefficient of friction;
- to be non-corrosive;
- good unctuosity (lubricating capacity).

There are two categories of lubricants used for bearing lubrication:

- fluid lubricants (oils);
- plastic lubricants (greases).

Table 8.1 shows comparison between fluid and plastic lubricants.

Although fluid lubricants have better characteristics than plastic lubricants, they cannot be used in all cases because of sealing difficulties.

Comparative values for lubricants

Table 8.1

Characteristics	Lubricant Fluid	Plastic
speed	any value	low and medium
friction	low (reduced)	high
unctuosity	excellent	good
service life	long	short
cooling effect	high	low
replacement	easy	difficult

Selection of lubricants

When selecting lubricants, much care is needed and all operating conditions and lubricant properties should be considered.

No lubrication system can be considered universal.

The most important criteria when selecting a lubricant have to be as follows:

- size of bearing
- speed
- load
- bearing operating temperature

These characteristics act upon lubricant viscosity as follows:

- the higher the bearing size, value of load and temperature, the higher the viscosity
- bearing speed acts by product D_m n, as shown in table 8.2.

Corelation between D_m n and lubricant type

Table 8.2

D_m n over	up to	Lubricant type
–	150×10^3	Mineral oil and grease with medium or high viscosity
150×10^3	300×10^3	Mineral oil with medium viscosity and grease
300×10^3	500×10^3	Mineral oil with low viscosity and grease
500×10^3	$1\,200\times10^3$	Mineral oil with low viscosity and lubricating equipment

Grease lubrication

Grease can be used to lubricate rolling bearings only when product D_m n $\leq 500\times10^3$ and it offers the following advantages:

- it is more easily retained in the bearing;
- it assures anti-corrosive protection to bearing as it is water-resistant;
- low expenses for sealing.

The grease quantity to be supplied shouldn't be excessive, otherwise rotation is braked, friction increases and also operating temperature without extending the bearing rating life.

The quantity of grease that is to be inserted in bearing seating should be as follows, considering the free space inside the housing:

- 1/2...3/4 of the free space in the housing, in case of normal speeds;
- 1/3 of the free space in the housing, in case of high speeds and speed limit;
- the whole housing space should be free, in case of low speeds and product $D_m\,n < 10\times10^3$.

The quantity of grease can be calculated as a function of bearing bore diameter using the equation:

$$G = K\,d^{2,5}\text{, g.}$$

where:

K = 1/900 - for ball bearings
K = 1/350 - for roller bearings
d = bore diameter, mm

Relubrication intervals in most cases can be experimentally determined and depend on:

- bearing type
- bearing size
- operating temperature
- grease properties

Grease service life and relubricating interval can be calculated from:

$$T_{ur} = k_0\left(\frac{14\times10^6}{n\,d} - 4d\right) f_1\,f_2,$$

where:

T_{ur} = service life or relubricating interval, in operating hours
k_0 = coefficient depending on the bearing type, table 8.3
n = speed, r/min
d = bore diameter, mm
f_1 = temperature factor, table 8.4
f_2 = factor depending on the operating conditions, table 8.5

Values for coefficient k_0

Table 8.3

Bearing type	Value of k0 Relubrication interval	Grease service life
Angular contact ball bearings Tapered roller bearings Thrust ball bearings	1	2
Cylindrical roller bearings Needle roller bearings	5	15
Deep groove ball bearings	10	20...40

Low values are valid for deep groove ball bearings with shields, 2Z type, or with seals, 2RS type, series 60, 62 and 63.

Values for factor f_1

Table 8.4

Temperature	70°C	85°C	100°C
Factor f_1	1	0,5	0,25

Values for factor f_2

Table 8.5

Operating conditions	Light	Moderate	Hard	Very hard
Factorul f_2	1	0,7...0,9	0,4..0,7	0,1....0,4

Bearing relubrication interval can be also determined using the chart - fig. 8.1, as a function of bearing type, bore diameter and speed.

Example:

A bearing 6208-2RSR is operated under reduced load (it is not considered for calculation), at a speed n = 1500 r/min, at a temperature of +60deg C, light operating conditions. What is the grease service life and relubrication interval?

Grease service life will be:

$$T_u = k_0\left(\frac{14\times10^6}{n\,d} - 4d\right) f_1\,f_2 = 32\,883\text{ hours,}$$

k_0 = 25 from table 8.3
d = 40 mm
f_1 = 1, from table 8.4
f_2 = 1, from table 8.5

Relubrication interval:

$$T_r = k_0\left(\frac{14\times10^6}{n\,d} - 4d\right) f_1\,f_2 = 13\,157\text{ hours,}$$

k_0 = 10, from table 8.3
f_1, f_2 = 1, from tables 8.4, 8.5.

From the diagram fig. 8.1, the value of the relubrication interval will be of 13 500 operating hours.

The grease quantity to be supplied can be determined using the equation:

$$G = K\,D\,B,\ g,$$

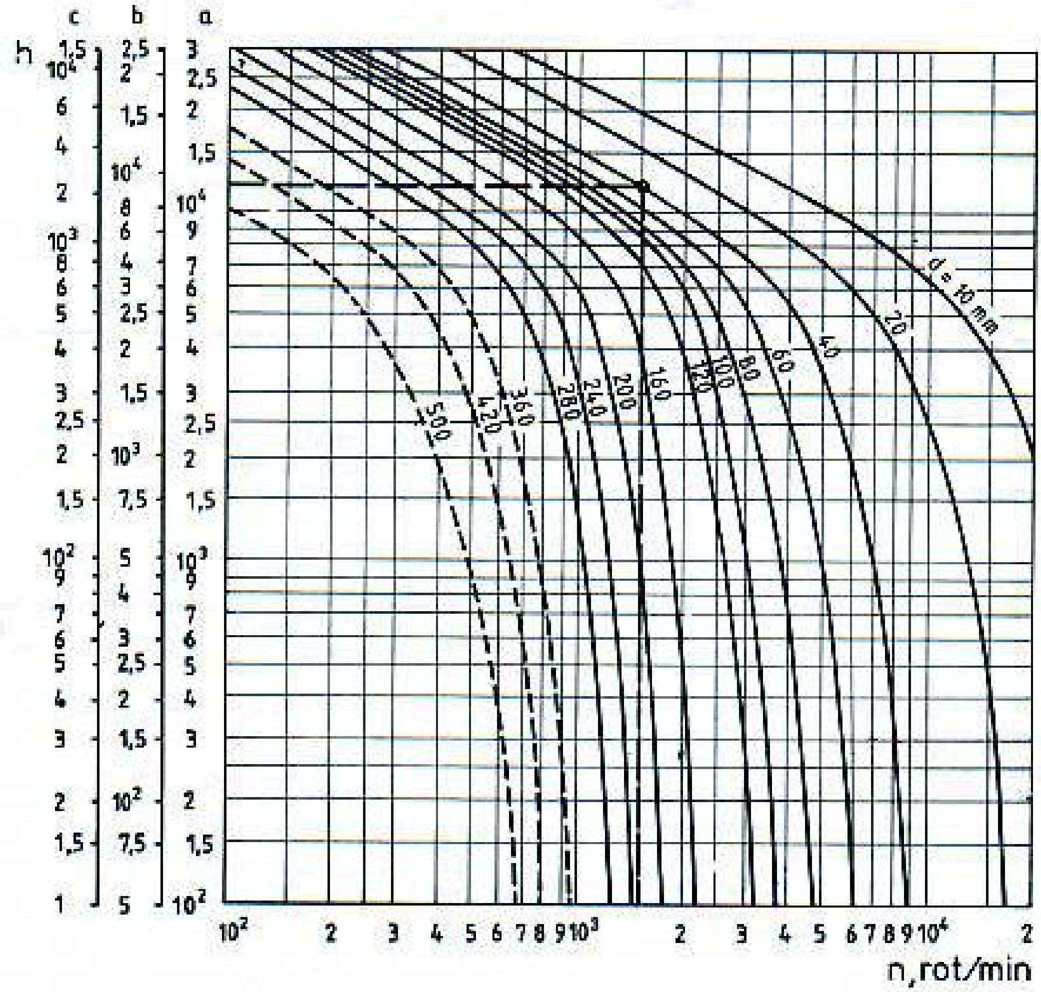
where:

G = grease quantity, g
K = coefficient depending on the relubrication interval, table 8.6
D = bearing outside diameter, mm
B = total bearing width for radial bearings, mm and total bearing height for thrust bearings, mm

Values for coefficient K

Table 8.6

Relubrication interval	K
weekly	0,0015...0,0020
monthly	0,0020...0,0030
yearly	0,0030...0,0045
after 2...3 years	0,0045...0,0055



Scale a; deep groove ball bearings
Scale b; cylindrical and needle roller bearings
Scale c; spherical roller bearings, taper roller bearings, thrust ball bearings, roller thrust bearings and needle roller bearings, cylindrical and needle roller bearings without cage, crossed roller bearings, spherical roller thrust bearings.

Fig. 8.1

The chart in fig. 8.1 applies to operating temperatures which do not exceed +70°C. For operating temperatures over +70°C, see table 8.4.

Grease service life can be defined as the period of time when it preserves physical and mechanical characteristics in time and oxidizing due to temperature and vaporization of base oil doesn't occur.

A more accurate calculation of grease service life, considering grease quality and bearing operating conditions (load, size, speed, temperature etc.) can be done using the equation:

$$L = 10^{a-(m_1+m_2+m_3)}$$

where:

L = service life, operating hours

a = exponent depending on the grease quality (a = 5,8...6,1)

$m_1 ... m_3$ = exponents which take into account the following factors:

$m_1 = 4{,}4 \times 10^{-6} D_m n$,

$m_2 = 2{,}5(P/C - 0{,}05)$,

$m_3 = (0{,}021 - 1{,}80 \times 10^{-6} D_m n)T$,

D_m = bearing mean diameter, mm,

n = bearing speeds, r/min,

P = equivalent radial load, kN,

C = basic dynamic load, kN,

t = bearing operating temperature, °C

When calculating the values of t, $D_m n$ and P/C, the following have to be considered:

- when bearing operating temperature is lower than +50°C, then t = +50°C
- when speed factor $D_m n < 125\,000$, then $D_m n = 125\,000$
- when ratio $P/C < 0{,}05$, then $P/C = 0{,}05$

Grease service life, as a function of operating temperature can be approximately determined using the diagram fig. 8.2.

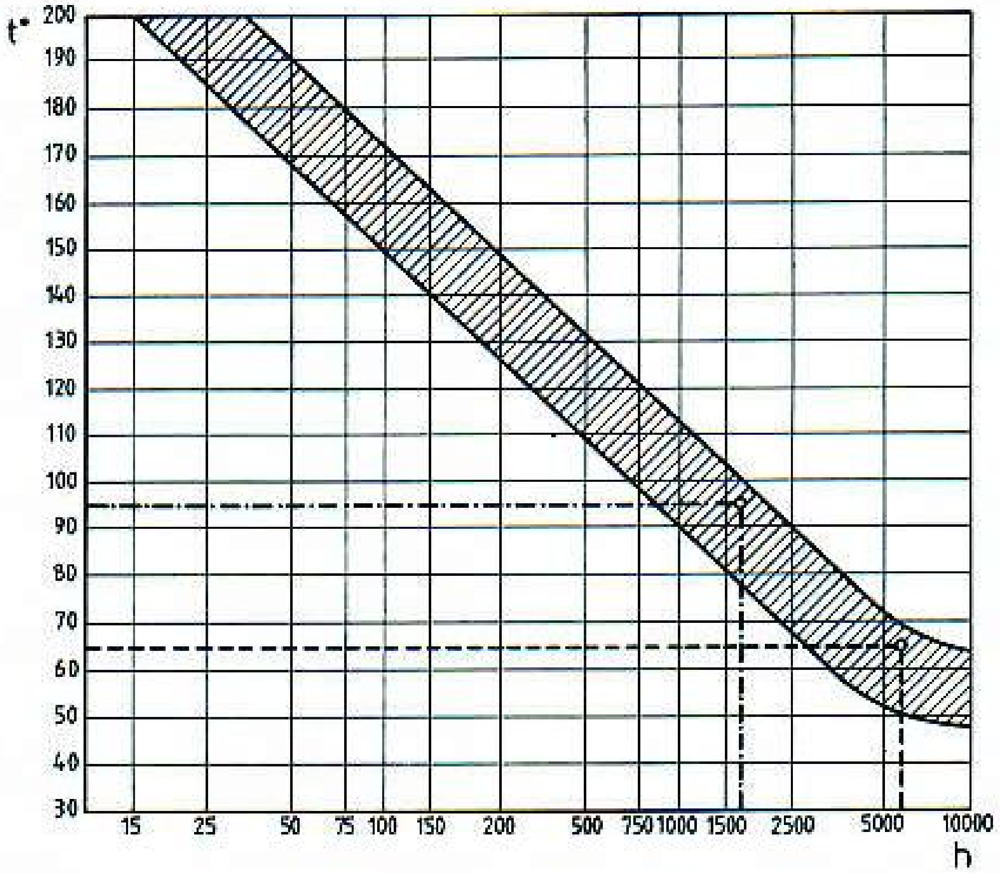


Fig.8.2

Example 1

A bearing 6210 operates under a load P_r = 5 kN, speed n = 3000 r/min at an operating temperature T = 50°C. What is the service life of the grease used for bearing lubrication?

C_r = 35,1 kN, tables on page 132, bearing 6210

$L = 10^{a-(m_1+m_2+m_3)} = 10^{6,1-2.273} = 10^{3,827} = 6\,214$ hours

a = 6,1, for Mobil grease,

$D_m n = 65\times3\,000 = 195\times10^3$
$P_r/C_r = 5/35,1 = 0,143$
$m_1 = 4,4\times10^{-6} D_m n = 0,858$
$m_2 = 2,5\,(P_r/C_r - 0,05) = 0,23$
$m_3 = (0,021 - 1,80\times^{-8} D_m n)65 = 1,118$
$m_1 + m_2 + m_3 = 2,273$

Example 2

For the same bearing and operating conditions as in Example 1, it is required to find the service life of the same grease at a temperature of T = 95°C.

$m_3 = 1,66$
$m_1 + m_2 + m_3 = 2,794$

$L = 10^{6,1-2,794} = 10^{3,306} = 1\,774$ operating hours

From the diagram fig. 8.2, we can find approximately the same value, respectively 6 000 operating hours at +65°C and 1 700 operating hours at +95°C.

Table 8.7 shows technical characteristics of usual grease, which are recommended for lubrication of sealed and shielded bearings, 2RS and 2Z types and also for rolling bearings in various assemblies and machines.

Technical characteristics for usual greases for bearing lubrication

Table 8.7

Grease main components		Dropping point °C	Temperature range (continuous running)	Application	Grease type, producer
Base oil	Thickener				
Mineral oil	Lithium soap	170°C-190°C	–30°C...+130°C	Ball, roller and needle roller bearings: - small and medium sized, - moderate speeds, - temperatures up to 70°C	- Mobilux 2-3, Mobil Austria, - Castrol Spherol SRB2, Castrol Germany - Shell Alvania R 2-3, Shell England - Aguila Nr30, Brugarolas Spain - UM 185 Li 2-3, Lubrifin Brașov
Mineral oil + additive for excessive pressure (EP)	Lithium soap	185°C-190°C	–30°C...+150°C	Ball and roller bearings, - moderate speeds, - heavy loads, shock loads, - continuous running temperature +130°C, - initial lubrication and relubrication at periods of 6-9 months	- Mobilux EP 2-3, Mobil Austria - Shell Alvania EP 2-3, Shell England - Beacon EP 2, Esso Germany
Synthetic oil (diesteric)	Lithium soap	180°C-230°C	–30°C...+130°C	Bearings for electrical motors, generators, electronic equipment, - small sizes, - light loads, - high speeds $D_m \times n \leq 1000 \times 10^3$	- Beacon 325, Esso Germany
Synthetic oil (diesteric)	Lithium soap	190°C-230°C	–60°C...+120°C	Bearings for electrical motors, generators, electronic equipment, - small sizes, - light loads, - high speeds $D_m \times n \leq 1000 \times 10^3$	- Izoflex LDS 18 Special A, Kluber Lubrication Germany
Mineral oil	Complex calcium soap	100°C-180°C	–30°C...+130°C	Bearings for general applications, - heavy loads, moderate speeds, - continuous running temperature 100°C	- Beacon 2-3, Esso Germany - Beacon EP1, Esso Germany - UM 170 Li Ca 2-3, Lubrifin Brașov
Synthetic oil	Without soap, synthetic thickener	indeterminate	–30°C...+250°C	Bearings for general applications, - large sizes, - low speeds $D_m \times n < 200 \times 10^3$, - high temperature	- Barierta 1S, Kluber Lubrication Germany
Synthetic oil + additive for excessive pressure (EP)	without soap, synthetic thickener	265°C	–54°C...+177°C	Spherical roller thrust bearings, roller thrust bearings etc., bearings operating with high friction, - moderate and high speeds, - low and high temperatures	- Mobilgrease 28, Mobil Austria
Synthetic oil	without soap, inorganic thickener	260°C	–50°C...+177°C	Bearing for general applications, - light loads, - high speeds, - low and high temperatures	- Armingras BT-2, Burgarolas Spain
			–30°C...+140°C	Cylindrical roller bearings, - moderate and high speeds $D_m \times n \leq 300 \times 10^3$	- Statburgas NUB12, Kluber Lubrication Germany
			0°C...+260°C	Roller bearings operating at high temperatures	- Mobiltemp 1-2, Mobil Austria

Oil lubrication

Oil lubrication can be used in any operating condition, but this kind of lubrication is compulsory when the value of the product Dmxn from table 8.2, namely $D_m\, n < 500 \times 10^3$ is exceeded for grease and when high temperatures occur in bearing. Then, oil has to lubricate and to remove heat from bearing.

Oils used for bearing lubrication can be:
- mineral oils, used up to a temperature of +150°C
- synthetic oils, used up to a temperature of +220°C

For a proper lubrication of bearings, low quantities of lubricants to reach the rolling elements are needed.

The lubricating systems must provide oil quantity necessary to prevent oil draining from bearing and heat removal in case of high speeds.

Most usual oil lubricating systems depending on factor $D_m\, n$ are given in table 8.8.

Oil lubricating systems

Table 8.8

Lubricating system	Operating conditions	Factor Dm n	Oil viscosity at 40°C (m^2/s)	Example in fig.
Oil bath	Bath is filled up to the lowest rolling element for horizontal shaft and 70-80% of bath width for vertical shaft	$< 250 \times 10^3$	$(17.....300) \times 10^{-6}$	8.3 a), b)
Oil bath with external circulation	Central tank, oil circulates under a pressure of 1,5 MPa. High speeds.	$< 600 \times 10^3$	$(45...175) \times 10^{-6}$	8.4
Oil injection	Oil is injected into the operating area under a pretssure of 0.1..0.5 MPa, with flow capacity of 0.5..10 l/min depending on temperature. Heavy loads and high speeds.	$< 900 \times 10^3$	$(13,5..80) \times 10^{-6}$	8.5
Oil spot	Oil in air current under a pressure of (0.05..0.5)MPa, flow capacity of (0,5..4) m^3/hour, 0.5..4)m/hour for small and medium-sized bearings, heavy loads and high speeds.	$< 1200 \times 10^3$	$(10...45) \times 10^{-6}$	8.6

Approximate values of oil kinematic viscosity at +40°C depending on the operating temperature are given in table 8.9.

Corelation between viscosity and temperature

Table 8.9

Temperature t°C over	Temperature t°C up to	Viscosity at 40°C, cSt
-	50	12...60
50	80	37...75,5
80	120	> 75,5
120	150	227

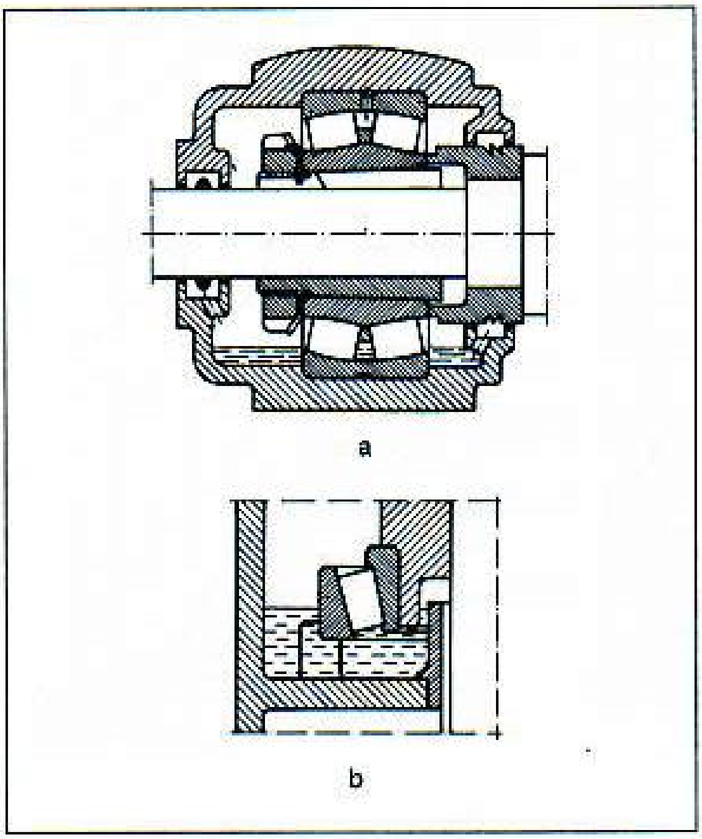


Fig. 8.3

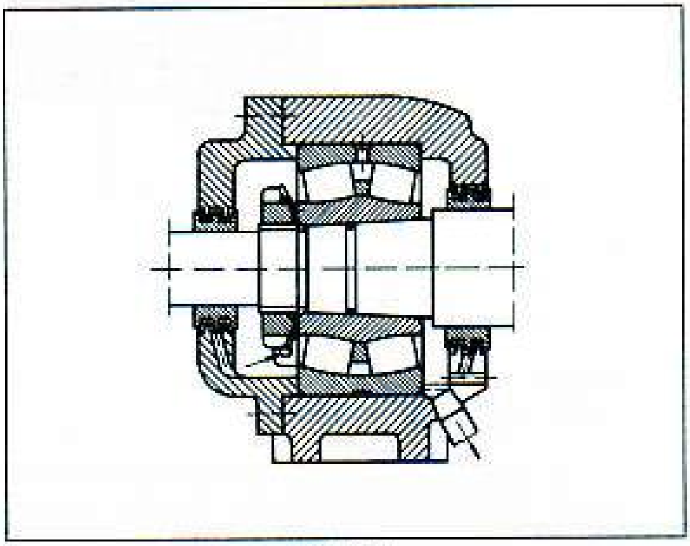


Fig. 8.4

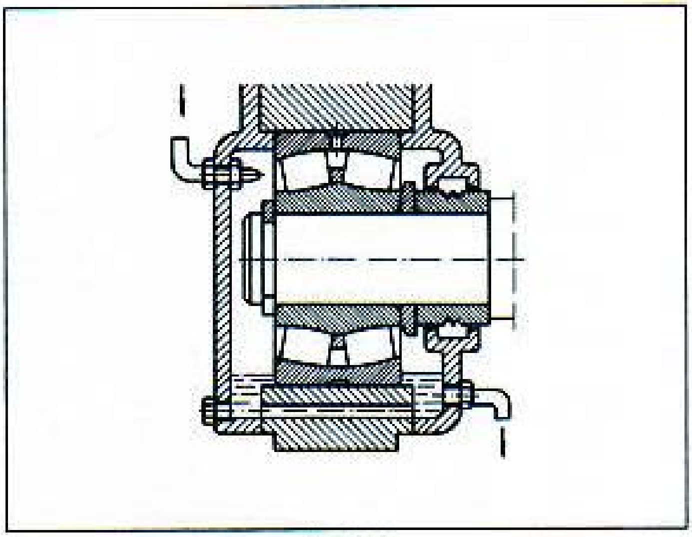


Fig. 8.5

Diagram fig. 8.7 shows kinematic viscosity classes at 40°C in accordance with ISO, its variation depending on the operating temperature (t °C) in relation to speed and bearing mean diameter (D_m).

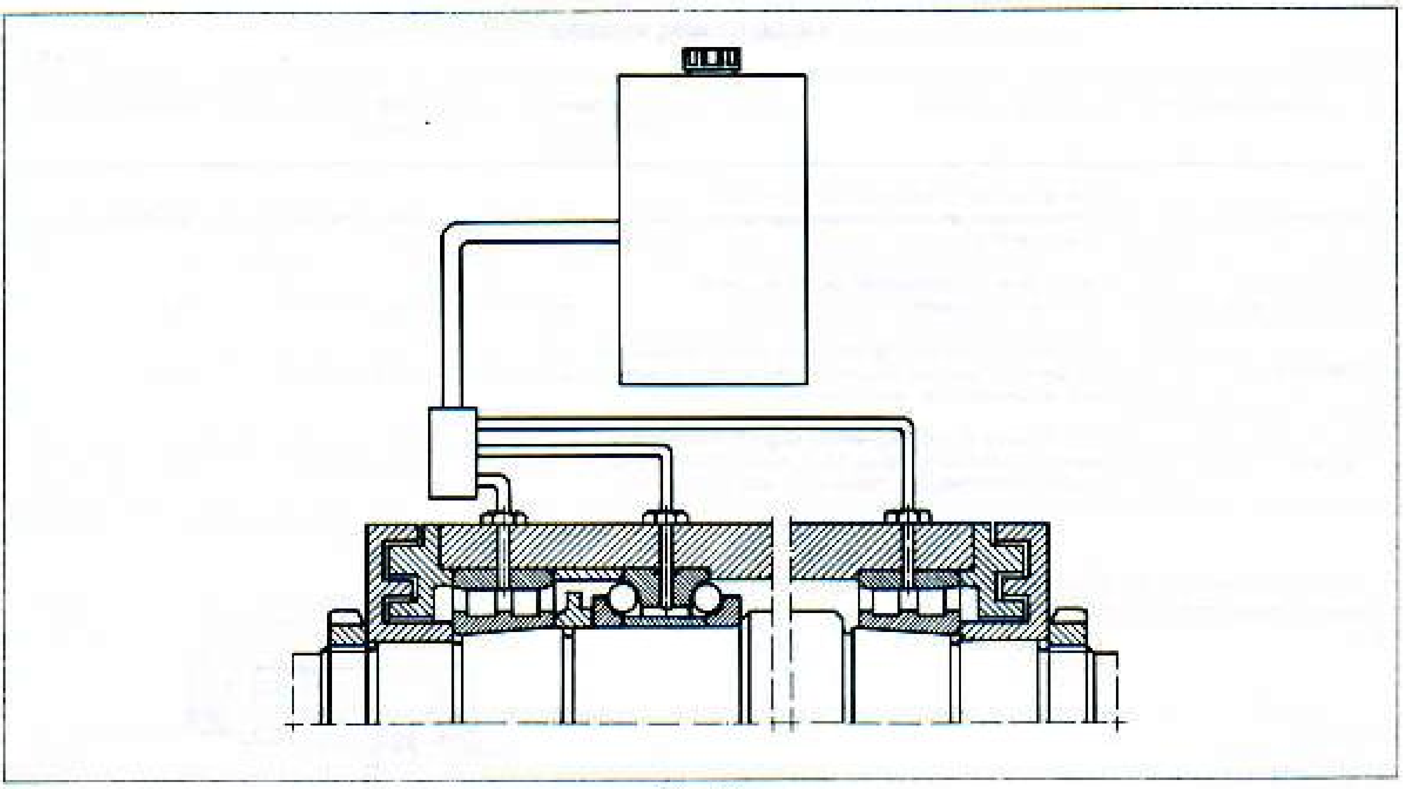


Fig. 8.6

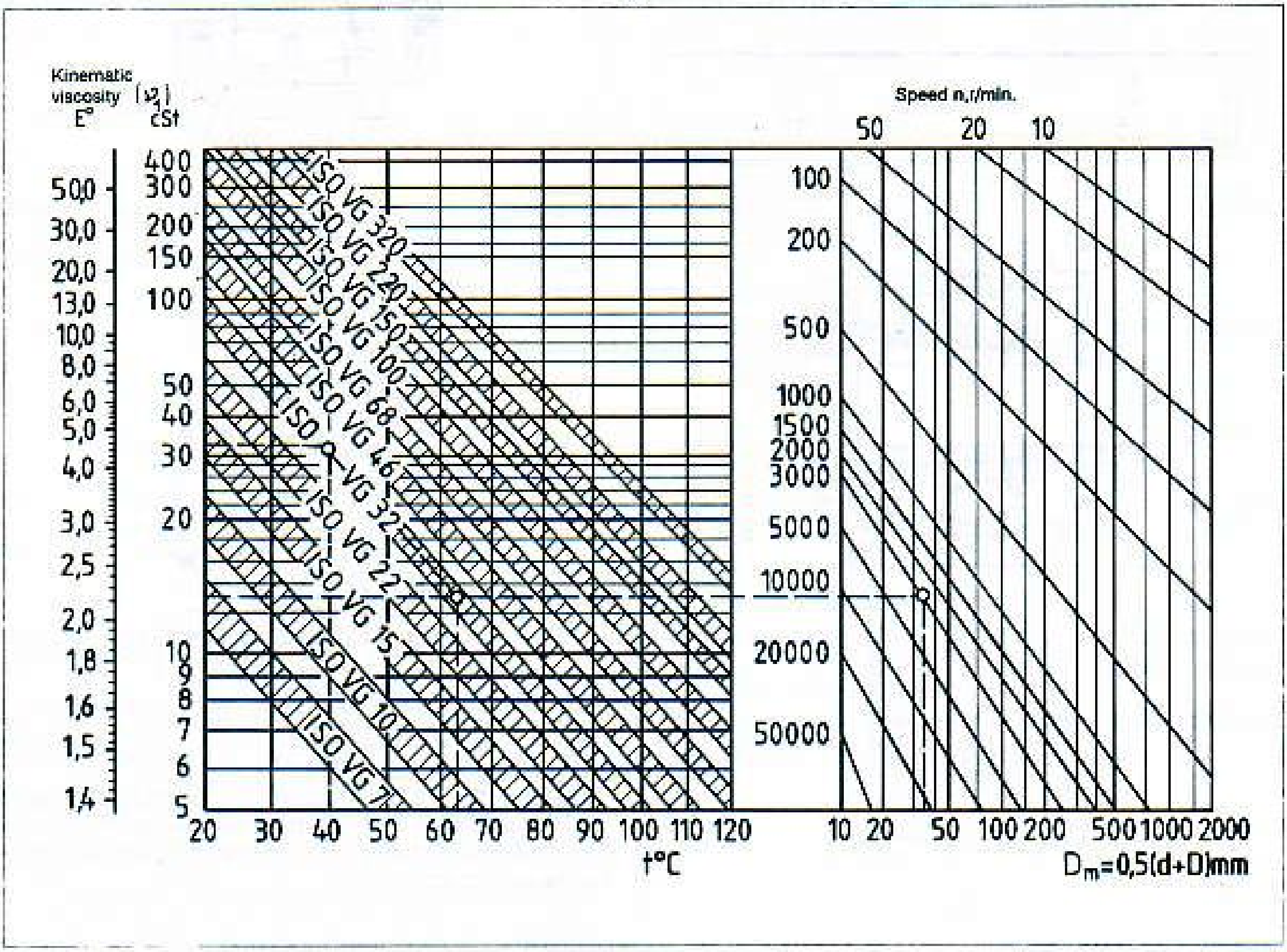

Kinematic viscosity
E°
cSt
Speed n,r/min.
ISO VG 320
ISO VG 220
ISO VG 150
ISO VG 100
ISO VG 68
ISO VG 46
ISO VG 32
ISO VG 22
ISO VG 15
ISO VG 10
ISO VG 7
t°C
D_m=0,5(d+D)mm

Fig. 8.7

Example

A bearing 6204 is to operate under a speed $n = 2\,000$ r/min at a temperature $t = +65°C$. $D_m = 0{,}5\,(d+D) = 35{,}5$ mm.

The viscosity of the oil for bearing lubrication is required.

From the diagram, for $D_m = 35{,}5$ mm, we can find viscosity at $+65°C$, $\nu_1 = 13$ cSt and viscosity at $+40°C$, $\nu = 32$ cSt.

Table 8.10 shows oils which are recommended by ISO for bearing lubrication. Values of kinematic viscosity at $+40°C$, mm^2/s are also given.

Recommended oils by ISO standards

Table 8.10

Class ISO	Kinematic viscosity at +40°C, mm²/s (cSt) mean	low	high
ISO VG 2	2,2	1,98	2,42
ISO VG 3	3,2	2,88	3,52
ISO VG 5	4,6	4,14	5,06
ISO VG 7	6,8	6,12	7,48
ISO VG 10	10	9	11
ISO VG 15	15	13,5	16,5
ISO VG 22	22	19,8	24,2
ISO VG 32	32	28,8	35,2
ISO VG 46	46	41,4	50,6
ISO VG 68	68	61,2	74,8
ISO VG 100	100	90	110
ISO VG 150	150	135	165
ISO VG 220	220	198	242
ISO VG 320	320	288	352
ISO VG 460	460	414	506
ISO VG 680	680	612	748
ISO VG 1 000	1 000	900	1 100
ISO VG 1 500	1 500	1 350	1 650