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Development of steels for transmission components

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DEVELOPMENT OF STEELS FOR TRANSMISSION COMPONENTS

Ovako has an extensive R&D since many years, an area that now is in an even higher intensity. Some of the R&D work is published in our technical reports.

Due to that Ovako of today has had a number of different company names and used various trade marks we have until now chosen to not have these reports publicly available. However, many of these technical reports contain valid data about material and steel grades that we still promote, but with other names etc.

The following Technical Report from 1983 is part of a series of technical reports we issued in the 1980's describing various aspects on how to achieve the clean steel we produce. See also Ovako Archive Technical report 1/1985, as well as 1/1997 and 1/2000 for later.

Data and processes in this report represent state of art at time of publishing, and is to a large extent base for our current technology and capability.

In this Technical Report there is used the following Company names and trade marks that no longer is used by Ovako AB.

SKF Steel; This company name is no longer used. The organization is now part of Ovako AB.

SKF; Is today a separate company with no link to Ovako.

Technical Report 8/1983

Development of Steels for Transmission Components

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SKF Steel

Introduction

The close relationship between steel quality and rolling bearing life has been known since the beginning of this century.
Few applications have made a more profound contribution to metallurgical process development than rolling bearings.
At SKF Steel, the acid open hearth process provided a steel that met demanding requirements for a very long time (1).
The development of the SKF MR process has resulted in a significantly improved metallurgical quality level (2).
Today, the steel produced at SKF Steel meets the demands of very high reliability and very long service life at high stresses in critical applications.
These properties are of increasing interest to the transmission industry as components are designed lighter and stresses become higher.

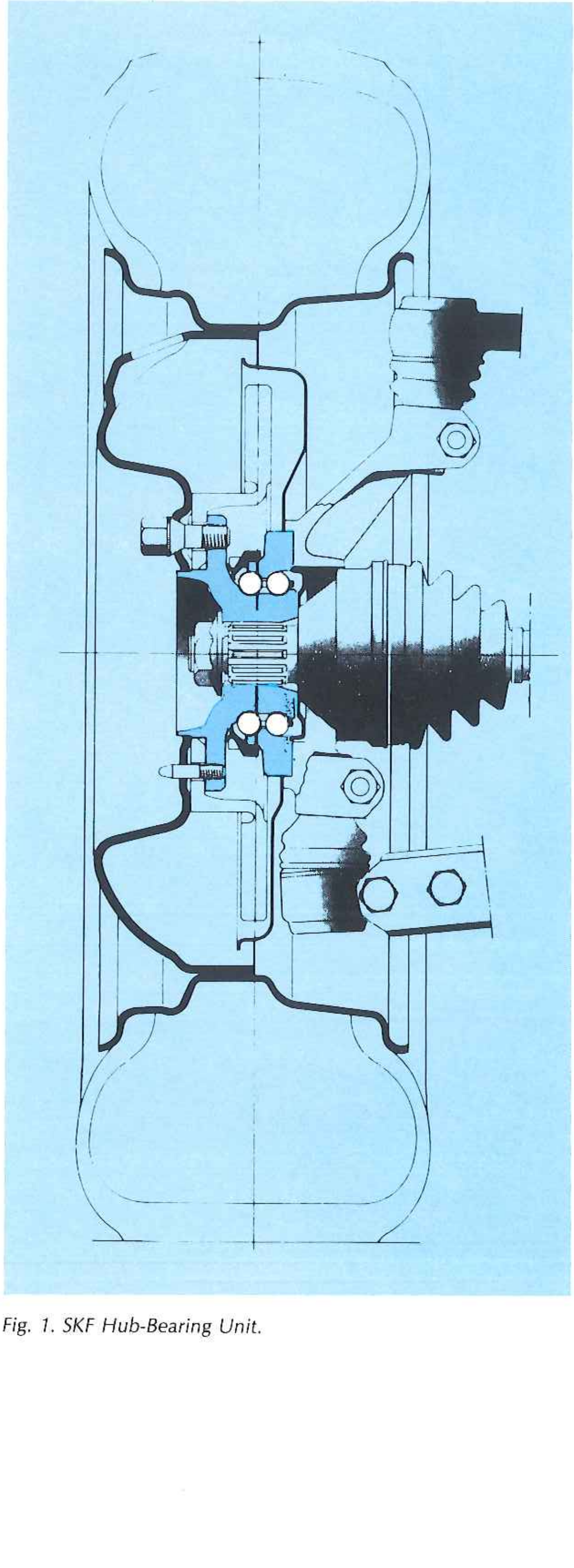

Fig. 1. SKF Hub-Bearing Unit.

Rolling bearings are often made of carburizing steel. One example is the compact railway bearing developed by SKF, *Fig. 2.* The rings of these bearings are slim and subjected to considerable stress. The properties of the steel are of fundamental importance not only to the performance of the bearing, but also to the bearing manufacture. Components made of carburizing steel acquire their properties by carburization of the surface and hardening and tempering. Consistent manufacture and properties demand a steel which is consistent in hardenability and cleanliness.

Fig. 2. SKF Tapered Bearing Unit.

Steel for Transmission Components

The car industry is a major user of carburizing steel. Carburizing steels dominate particularly in gear boxes of cars and in the transmissions in other vehicles. Metallurgical demands on steel for transmissions have traditionally not been as high as those for carburizing steel for rolling bearings. Development in the automotive industry during the later part of the 1970s, *Fig. 3,* has resulted in rapidly increasing demands on the steel (3—10). The developments include:

— Smaller transmissions
— Higher power outputs
— Stricter demands on noise levels
— Higher demands on efficiency in component processing
— Continued demands for reduced material costs.

Today, the relationship between the properties of steel and the performance of transmission components almost is as obvious as the the relationship between steel quality and rolling bearing performance.

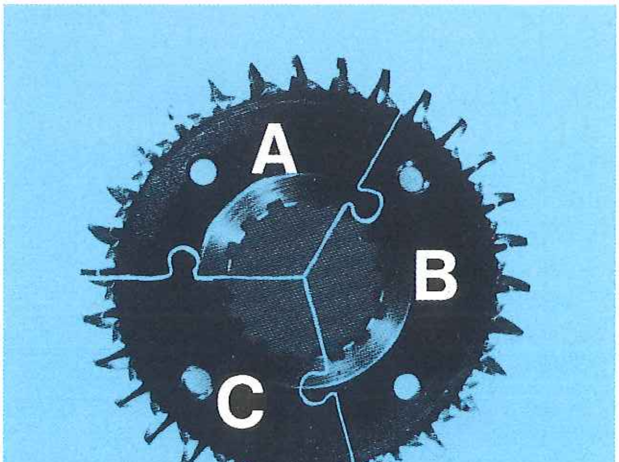

Fig. 3

A. SERVICE CHARACTERISTICS
B. MANUFACTURING COSTS
- *Forming*
- *Machining*
- *Heat treatment*

C. MATERIAL COSTS

Correct Steel for Top Performance

A gear is subjected to various forms of stress during operation. These can most easily be explained by the different types of damage that occur in gears:

— case crushing
— pitting
— wear
— impact fracture
— fatigue failure.

The correct choice of steel and heat treatment, as well as the correct design and processing, are fundamentally important, if damage to a gear box subjected to high stresses is to be avoided. Decisive metallurgical factors for gears in high stress transmissions are:

— consistency in chemical composition
— freedom from harmful non-metallic inclusions.

Consistency in Chemical Composition

Consistency in chemical composition is fundamentally important in the production of carburizing steel components. The development of new more efficient methods highlights this demand, *Fig 4.*

Control of the pearlitic structure, *Fig. 5,* is a precondition for successful machining.

Wide variations in the composition of the steel from heat to heat result in variations in the hardness and structure of the component. Such variations result in inferior surfaces and tolerances.

Development towards controlled cooling (simplified normalization) integrated in the forging process, *Fig. 6,* puts even higher demands on consistency in chemical composition, since the equipment is geared to the processing of forged components in high-speed, high-volume production.

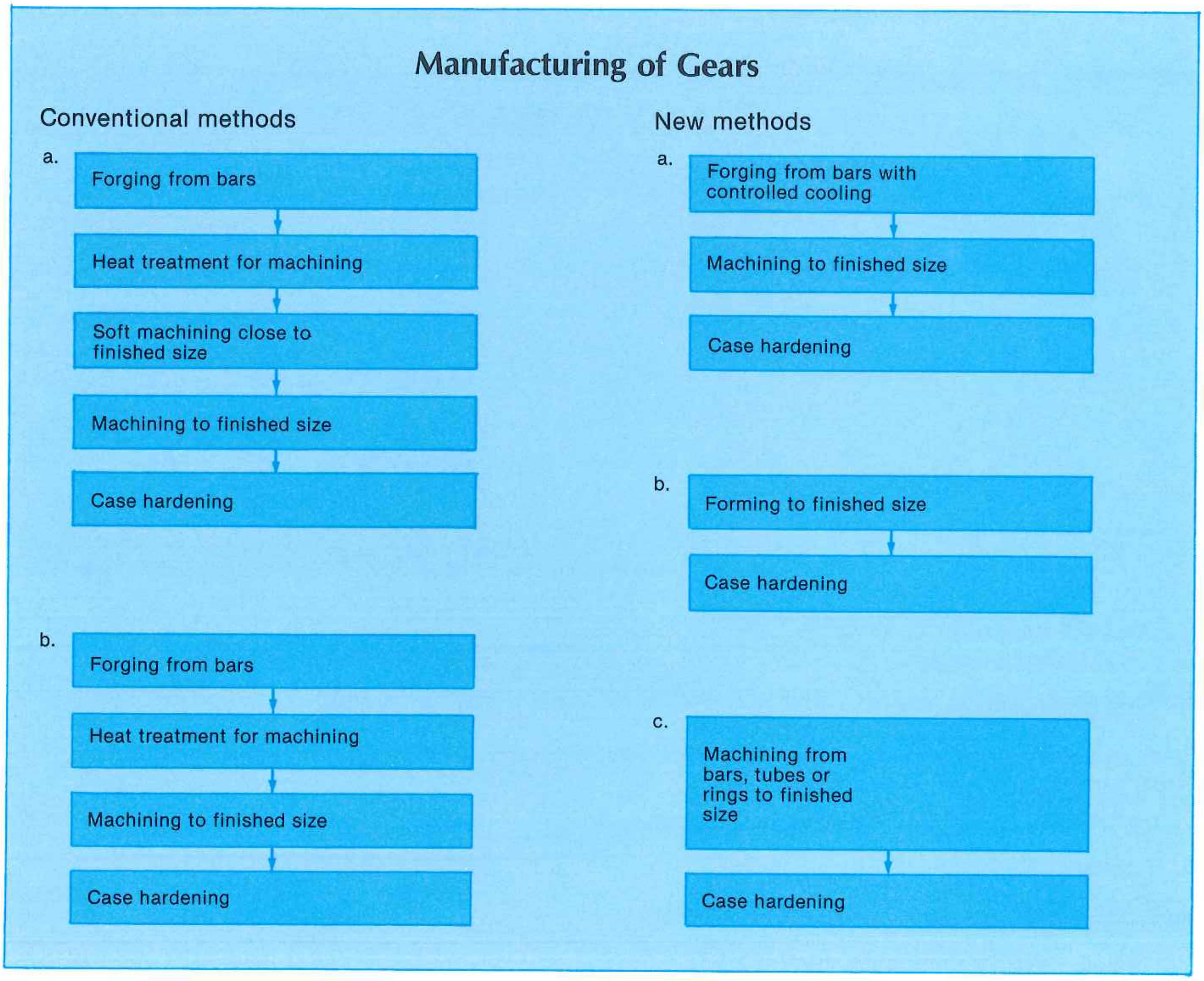

Fig. 4

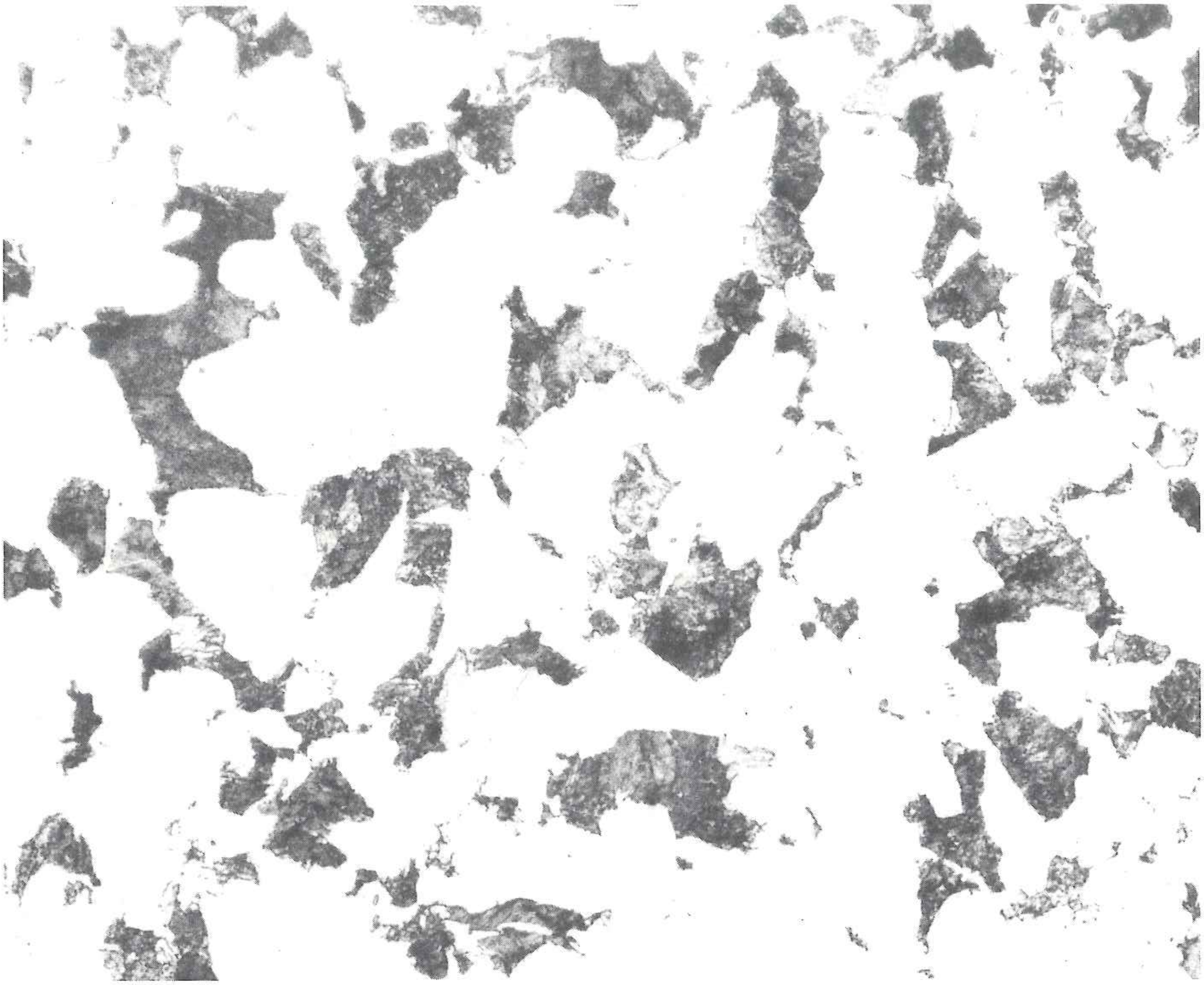

Fig. 5

In-line heat treatment of forgings

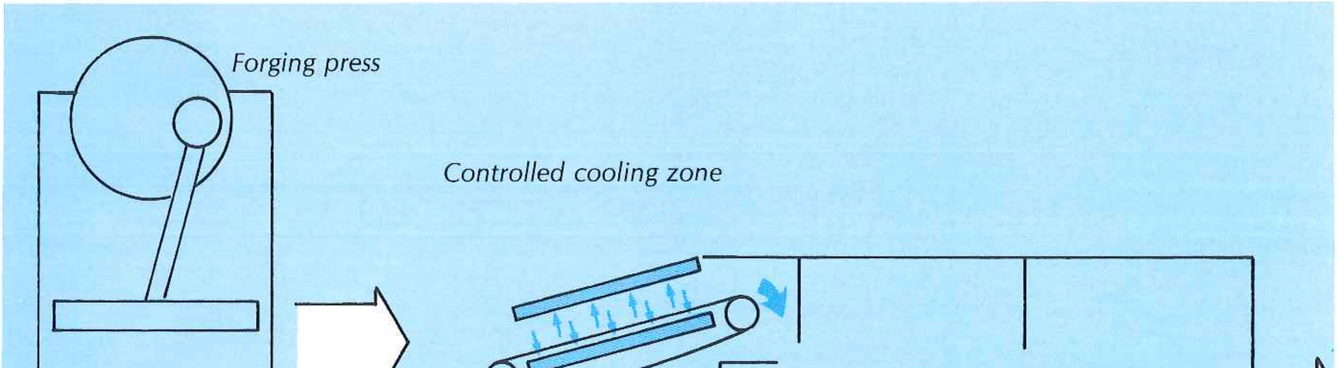

Fig. 6 In-line heat treatment of forgings

Hardenability

Hardenability is a property that determines hardness at a certain depth after quenching. Should the same hardness be required at a greater depth, a steel with higher hardenability must be used.

Hardenability is frequently measured in an end-quench (Jominy) test, *Fig. 7.* A wide Jominy-band results in variations in properties, such as strength and toughness. *Fig. 8* shows the hardenability ranges for two SAE H-band steels.

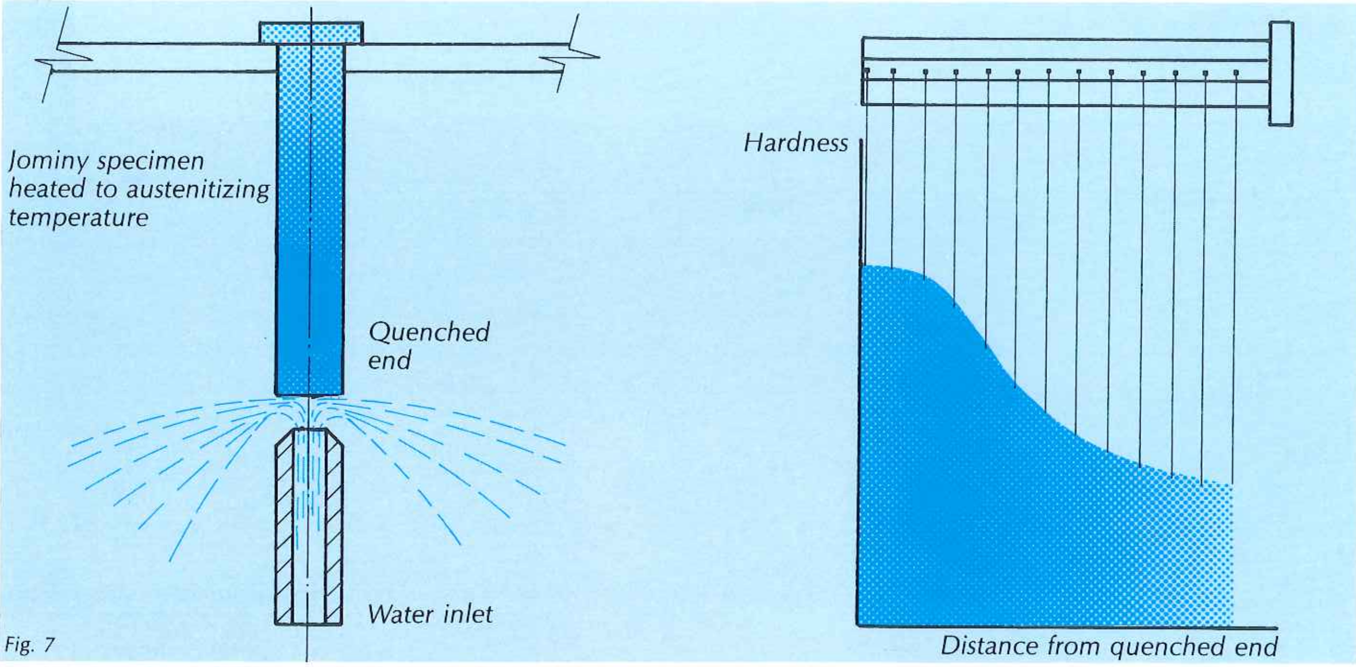

Fig. 7

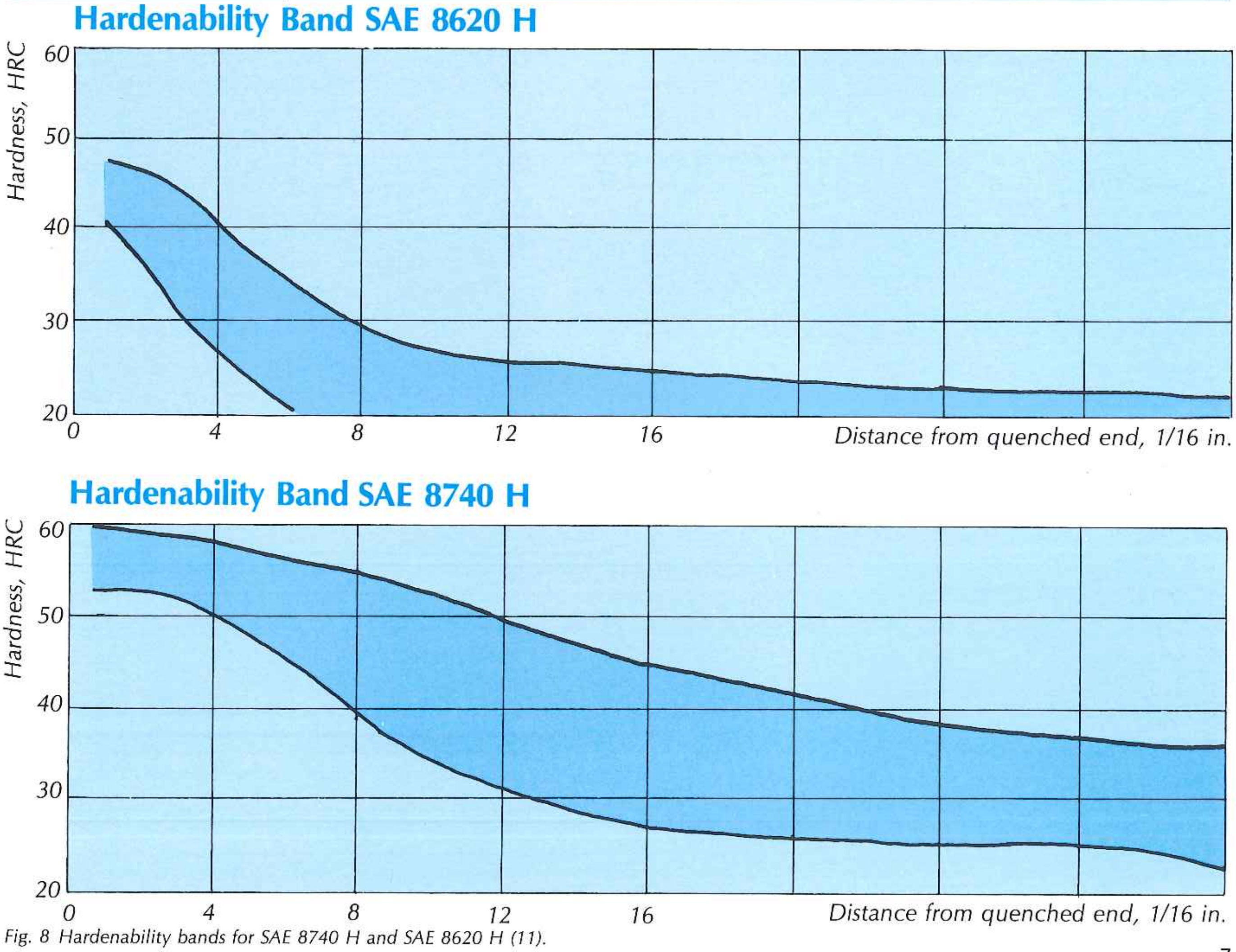

Fig. 8 Hardenability bands for SAE 8740 H and SAE 8620 H (11).

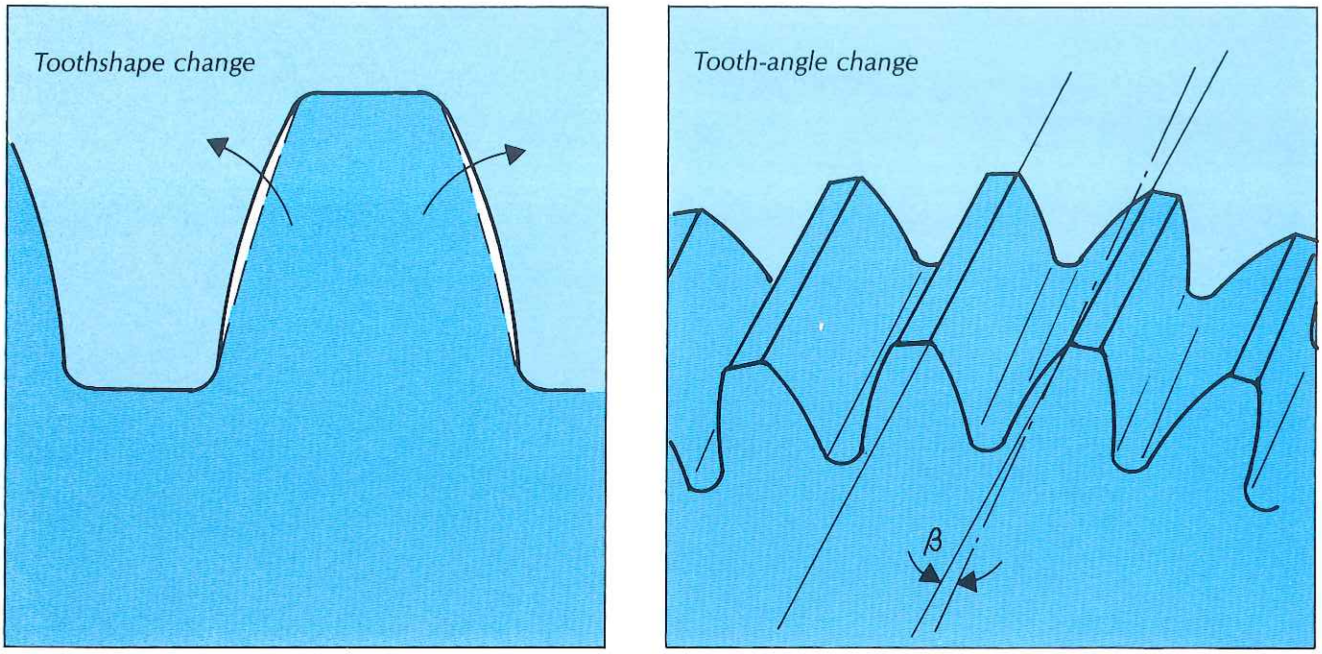

Fig. 9. Examples of distortions in gears.

Distortion

As a result of the transformations that always take place in steel during hardening, volume changes occur in transmission components. The distortion can never be entirely eliminated but must be predictable and consistent. Above all, consistent hardenability in and between heats must be maintained so that the dimensional changes can be compensated for in the earlier processing. *Fig. 9* shows examples of such distortions.

SKF Steel Extra-hardenability Controlled Carburizing Steels

SKF Steel's Extra-hardenability Control (12) offers an opportunity to optimize the machining process and achieve the properties and the consistency which enable transmission components to withstand severe operating conditions. This is now available for steel grades SKF 126 (SAE 4168H) and SKF 152 (SAE 8620H).

Fig. 10 shows an example of the SKF Steel Extra-hardenability Control procedure. The customer simply specifies three points (or less) on the desired Jominy-curve. The steel is then produced to match these requirements with high precision (13).

Different sizes and types of transmission components require different hardenability and undergo different distortions. This means severe demands on flexibility and precision with regard to the chemical composition and also very high consistency for one standard steel grade. *Fig. 11* shows how different transmission manufacturers require different hardenability in order to give their various transmission components optimal properties.

Examples of hardenability

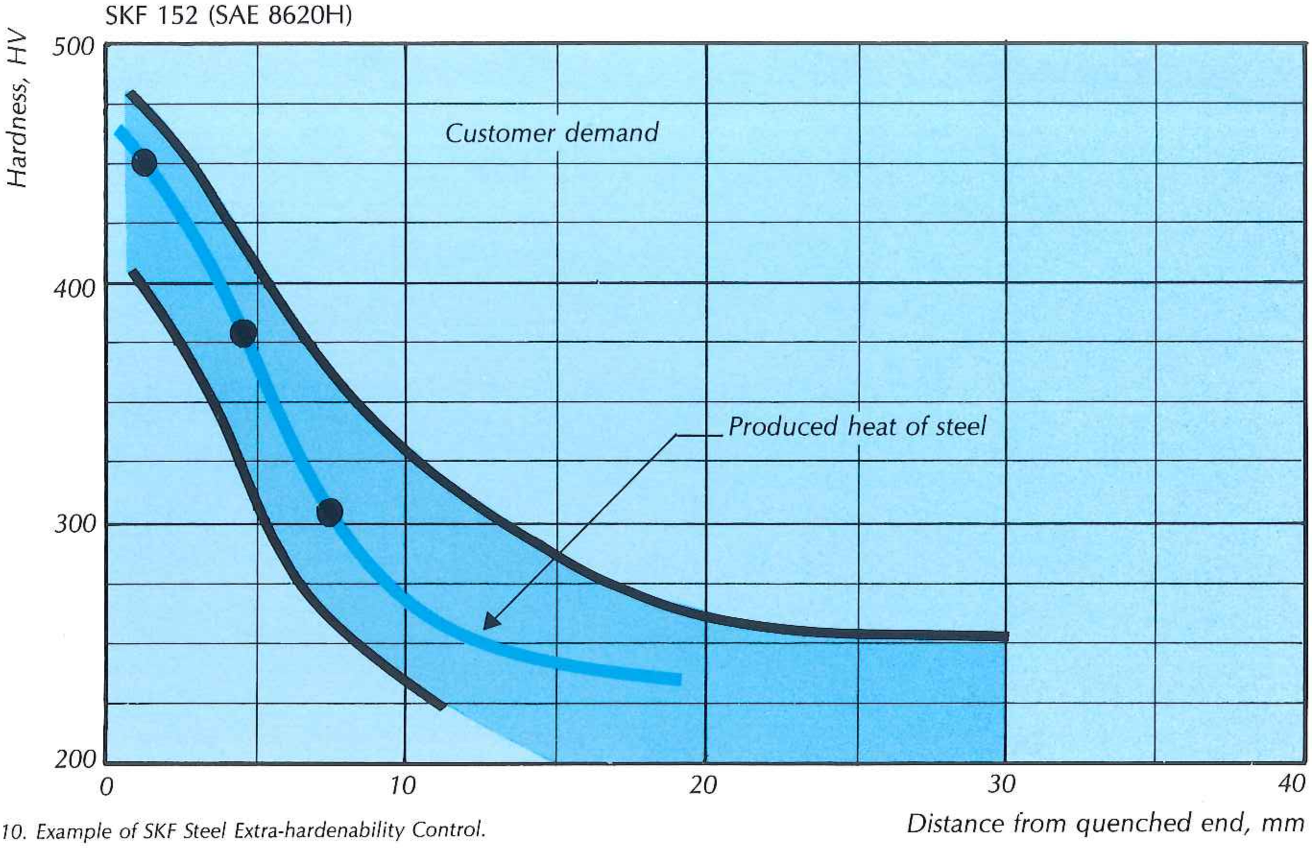

Fig. 10. Example of SKF Steel Extra-hardenability Control.

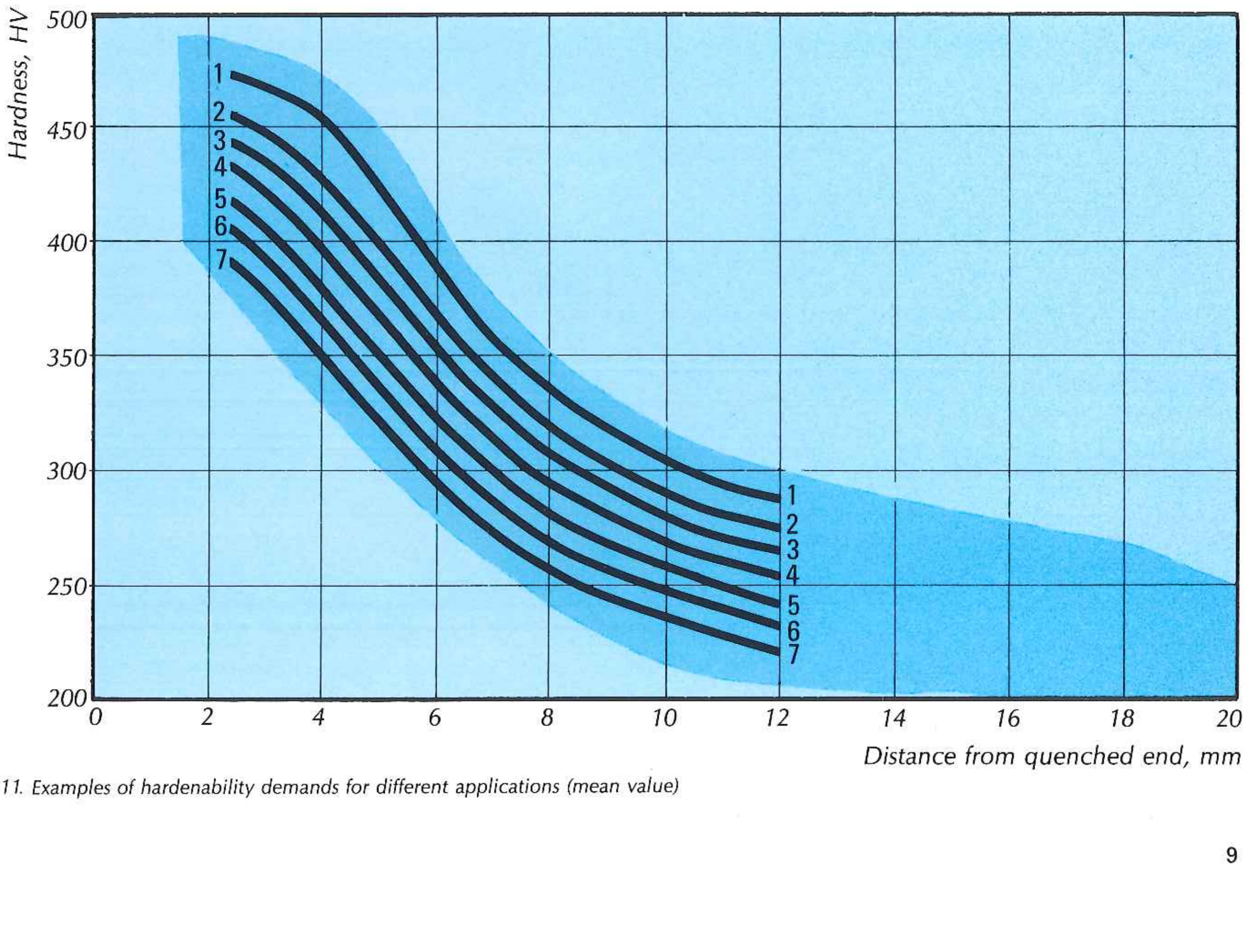

Fig. 11. Examples of hardenability demands for different applications (mean value)

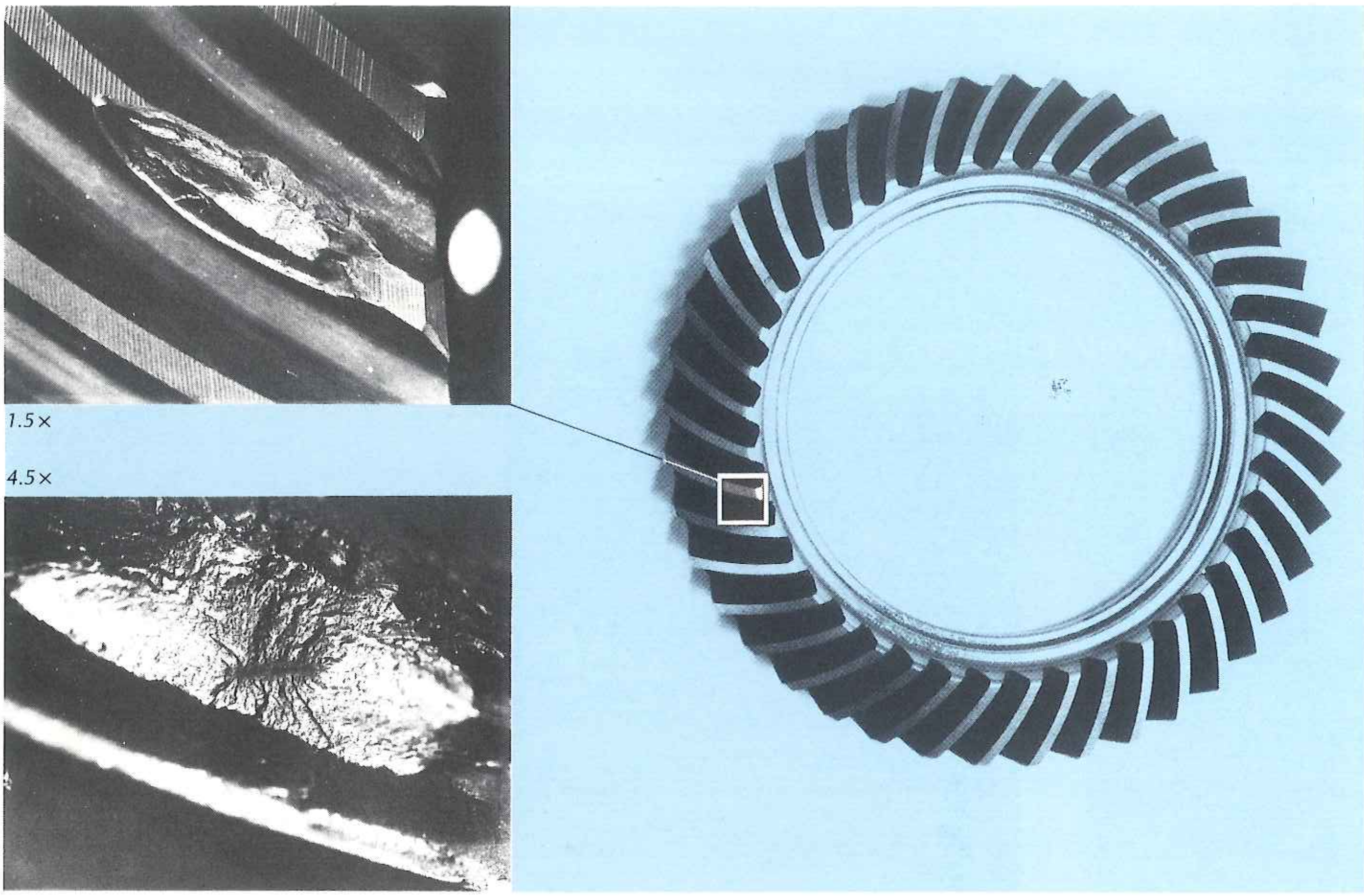

Fig. 12. Inclusions in a crownwheel.

Non-Metallic Inclusions

Components with high hardness, which are subjected to high stress require a low content of non-metallic inclusions. For practical reasons the relationship between inclusions and failures in transmissions is not as well documented as for rolling bearings. Failure analyses of damaged gears do, however, show that inclusions initiate fatigue failures. *Fig. 12* shows a crownwheel which failed due to inclusions in the steel. With smaller transmission components subjected to higher stresses, a low content of harmful inclusions is a decisive factor in component performance.

SKF Steel Standard Cleanliness Specifications for Carburizing Steels

SKF Steel's cleanliness specifications (14) are developed for high performance requirements and therefore adhere to strict cleanliness demands. In *Fig. 13* the SKF Steel standards are compared to the ASTM A534 specification for carburizing bearing steel.

Conclusions

Developments in the transmission industry show a trend towards lighter components with the ability to withstand high stress. This demands increased use of steel with high hardness, and the requirements of the transmission industry will correspond to the steel quality requirements of the rolling bearing industry.
Backed by its lengthy experience SKF Steel expands and intensifies its cooperation with the transmission industry in order to develop better components at minimum cost.
Three important metallurgical parameters in this development are:
Flexibility
Reproducibility
Cleanliness

SKF Steel Bearing Quality Carburizing Steels								
Oxygen Content:	Maximum 25 μg/g (0.0025%, 25 ppm)							
Macro-Inclusions:*	Maximum 60 mm/m² (0.22 in/ft²)							
Micro-Inclusions:	A		B		C		D	
	Thin	Heavy	Thin	Heavy	Thin	Heavy	Thin	Heavy
	3.0	2.0	2.0	1.5	1.0	1.0	1.5	1.0
ASTM A534 a)	3.5	2.5	3.5	3.0	3.0	2.0	2.5	2.0
b)	3.0	2.0	3.0	2.5	2.5	1.5	2.0	1.5

** Well within the limits set by AMS 2301 (certified on request).*
a) Open hearth quality.
b) Electric furnace quality.

SKF Steel Premium Bearing Quality Carburizing Steels								
Oxygen Content:	Maximum 15 μg/g (0.0015%, 15 ppm)							
Titanium Content:	Maximum 30 μg/g (0.0030 %, 30 ppm)							
Macro-Inclusions:*	Maximum 15 mm/m² (0.05 in/ft²)							
Micro-Inclusions:	A		B		C		D	
	Thin	Heavy	Thin	Heavy	Thin	Heavy	Thin	Heavy
	2.0	1.5	2.0	0.5	0	0	0.5	0.2

** Well within the limits set by AMS 2300 (certified on request).*

Fig. 13

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