Strip steel
for flapper valves
Engineered steels for challenging applications

Flapper valves must be capable of working continuously for long periods without failure. This places stringent requirements on materials, especially on bending and impact fatigue strength. We can supply strip steel for flapper valves, which meet the most demanding customer specifications.

Sandvik offers a program of a carbon steel, Sandvik 20C, and two martensitic, stainless chromium grades, Sandvik 7C27Mo2 and Sandvik Hiflex. All grades have good flatness and surface finish, excellent thickness tolerances, high purity levels and good blanking properties. The stainless steels are recommended where corrosive conditions require superior performance.

The stainless steels, and especially Sandvik Hiflex, have improved fatigue properties, compared with the carbon grade. These properties can be utilised by the valve designer. The valve lift, for example, can be increased, resulting in a more efficient compressor because of lower flow losses across the valve. Alternatively, the tongues can be made shorter with the same valve lift, which reduces the size of the compressor. This gives the end user many advantages and leads to savings on both material and space.

Strip steel can be slit to the required width and the edges can be shaved to a very high standard of smoothness, if specified. Close width tolerance requirements can also be met in the slitting line.

Standard thicknesses in all grades are available from stock for immediate delivery.

Brief descriptions are given below. For more detailed information, please refer to the enclosed data sheets.

Sandvik 20C
Carbon steel with 1% C offering high fatigue strength.

Sandvik 7C27Mo2
Martensitic, stainless chromium steel with 0.38% C, 13.5% Cr and 1.0% Mo. This grade is the first choice when higher fatigue strength is required. It is also suitable when the environment, e.g. moist air, calls for a stainless steel.

Sandvik Hiflex™
This is the new generation of Sandvik 7C27Mo2 and the optimum choice for flapper valve steel. Fine tuning of the micrometallurgy and strip production has resulted in a material with even higher bending fatigue strength and a 25% increase in impact fatigue strength, compared with the normal Sandvik 7C27Mo2.

Sandvik Hiflex is well suited to use in carbon dioxide compressors for air conditioning, where higher pressures and temperatures place increasing demands on the valve material.

Recommendations are for guidance only, and the suitability of a material for a specific application can be confirmed only when the actual service conditions are known. Continuous development may necessitate changes in the technical data without notice.

Sandvik and Hiflex are trademarks owned by Sandvik Intellectual Property AB.

Strip steel for flapper valves is one of the most advanced products in our program. To fulfill the tough demands placed on this steel, we utilise the experience we have gained from more than 100 years of strip production.

We also have our own metallurgy and can control the whole production chain from steel melt to finished product. This enables us to produce steels with consistent and reliable properties, which gives more efficient valves with longer lifetime. In close co-operation with our customers and end users, we develop our steels continuously for the flapper valves of today, and tomorrow.

Sandvik’s flapper valve steels are used in:

- Refrigerators and freezers
- Air conditioning equipment
- Heat pumps
- Brake systems
- Industrial air compressors
- Vacuum pumps

Our customers benefit from our experience and production

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A flapper valve is subjected to bending stresses when it opens, and impact stresses when it closes and hits the valve seat. This load pattern is repeated billions of times during a compressor’s lifetime and, therefore, the fatigue properties are of utmost importance. The illustration to the right shows what happens during one load cycle. Fatigue strength is affected by a range of factors:

- Microstructure
- Static strength
- Non-metallic inclusions
- Surfaces
- Edge finish
- Residual stresses and relaxation

Sandvik’s flapper valve steel is produced with these factors in mind so that our customers can rely on excellent and consistent material properties, from delivery to delivery. See also page 6.

In addition to the above factors, the design and manufacture of the flapper valves greatly influence fatigue properties.

**Bending fatigue**

Reversed bending fatigue strength (mean stress = 0) is tested in our mechanical testing laboratory. In the enclosed data sheets, the fatigue limit at a failure rate of 5% is given.

In practice, flapper valves are often subjected to fluctuating bending stress, with the minimum stress = 0. In our data sheets, we give values also for fluctuating bending stress, which have been calculated from our test values with the aid of a Goodman diagram and Gerber’s formula.

The fatigue strength values that we present in our data sheets are valid at 20°C (68°F). However, tests have shown that the grade Sandvik 20C can be used up to 150°C (302°F) and Sandvik 7C27Mo2 and Sandvik Hiflex up to 300°C (570°F) with retained fatigue strength properties.

**Impact fatigue**

Every time a flapper valve hits the stop when opening and the valve seat when closing, the valve material is affected by the impact. This may eventually lead to fatigue failure, which appears around the top of the tongue as small chippings, from which further cracks may propagate.

The material’s resistance to impact fatigue is tested in a machine designed by Sandvik, which simulates a compressor. The impact velocity is measured with a laser sensor, and the test result is presented in our data sheets as the maximum allowable impact intensity.

As can be seen in the diagram to the left there is a considerable difference in impact fatigue strength between the grades.
Factors influencing the fatigue strength

Microstructure
After hardening, the steel consists of a very fine-grained martensitic matrix with evenly distributed carbides. The production process ensures that no decarburisation takes place as this would diminish the strength properties. The microphotos show the structure of a carbon steel and a stainless, martensitic chromium steel.

Static strength
Static strength can be measured by tensile testing, which relates to the hardness of a material. A high tensile strength is required to enable the material to withstand the fatigue forces a flapper valve is subjected to throughout its service life. If, however, the static strength of the material is too high this will make it brittle, causing cracks to form.

Sandvik flapper valve steels have a consistent static strength optimized to provide maximum fatigue strength.

Fatigue strength

The fatigue strength as a function of the tensile strength.

Non-metallic inclusions
There is no such thing as an inclusion-free steel. However, careful selection of the raw material and an optimum steel melting process enable us to produce flapper valve steels with low contents of very small and well-distributed non-metallic inclusions. The number of detrimental inclusions is kept to a minimum.

Sandvik constantly monitors the level of non-metallic inclusions, in order to ensure that the ongoing process development will result in further improvement in the metallurgical quality.

Surfaces
Fatigue fractures initiate easily at surface imperfections. Sandvik’s flapper valve steel is, therefore, delivered with very smooth, bright-polished surfaces, virtually free from scratches and other detrimental surface defects. This reduces the risk of catastrophic failures. Our internal product specifications specify the maximum allowed values for scratches and other surface defects, e.g. pits and roll marks.

The surface of a material is, however, never absolutely smooth, but has some degree of roughness. The surface roughness standard for our flapper valve material is very high. In our data sheets we present values for the roughness criteria $R_a$ and $R_{\text{max}}$.

Edge finish
The edge finish is as important for fatigue properties as the surface finish. Initiation of fatigue fractures can be avoided only if the edges are smooth. Strip for flapper valves can, therefore, be ordered with shaved edges. See also the heading “Tumbling” on page 9.

Residual stresses and relaxation
Residual stresses in the strip surface and edges have a strong influence on the fatigue resistance of the flapper valve. Residual compressive stresses are favourable, as they counteract the pulsed tensile stresses in a flapper valve, when it deflects. Sandvik’s flapper valve steel has such beneficial residual, compressive stresses in the surfaces in the “as delivered” condition. Their intensity is further increased during the tumbling operation.

The residual compressive stresses in the surface may decrease somewhat during service. This is referred to as relaxation and it leads to decreased bending and impact fatigue strength. Tests with Sandvik’s two stainless flapper valve steels have shown that they have little tendency for relaxation. Sandvik HiFlex displays considerably less than Sandvik 7C27Mo2.
Valve design and manufacture

A well designed component and careful manufacturing are essentials for the function and service life of a flapper valve. Only then, the excellent properties of the valve steel can be fully utilised.

Valve design
When designing flapper valves, it is important to avoid core and other such as small radii and sudden changes in cross-sectional area. Also, narrow slots should be avoided as they are difficult to achieve satisfactory rounding of the edges during tumbling. See also below under “Tool design”.

Blanking
Hardened and tempered steel increases the load, by up to 2.5 times, on the edge of a blanking tool compared to an annealed steel. Because the material thickness in flapper valves is usually thin, the load on the tool edge will still be relatively small.

Stainless steel generally causes greater tool wear and higher burrs than carbon steel, but otherwise the blanking properties of the different steel types are similar.

Tool design
The design of valves is closely linked to the design of punches and dies. Co-operation between the designers of the product and the tool is, therefore, extremely important. The following points should then be taken into account:
1. Corner radii should be made as large as possible.
2. Slender tool sections should be avoided.
3. Light-gauge punches must be designed with a cylindrical head.
4. Hole diameters should be larger than 3 x the strip thickness. For smaller hole sizes, the punch should be accurately guided in a spring-loaded stripper.
5. The blanking clearance should be chosen so that the punch does not break and the slug does not ride up.

Clearance between punch and die
Usually a sheared edge, with a narrow shear zone and a wide, even break edge zone with low burr height, is preferred. Also, low burr height must be combined with the longest possible tool life. Therefore, we recommend a blanking clearance of 2-10% of the strip thickness, depending on the actual strip thickness. A smaller clearance is only justified when the hole slug tends to ride up with the punch.

Tool materials
High-speed steel (AISI M2) and cemented carbide are used mostly for the manufacture of punches and dies. In the majority of cases, we recommend M2. Sandvik Hard Materials supplies suitable cemented carbide grades. For the choice of grade, we recommend reference to a specialist manufacturer or quality tooling.

Flatness
Our flapper valve steel is supplied with a maximum out-of-flatness of 0.20% of the nominal strip width, both across and along the strip.

Blanking involves plastic deformation of the layer next to the blanked edge surface. This may cause out-of-flatness in long and narrow valves. However, the influence diminishes with increasing hardness and decreases with decreasing material thickness.

Clear tool edges, the recommended blanking clearance and high pressure on ejectors and strippers are the best means of reducing this type of out-of-flatness. It can be further reduced by heat treatment and tumbling. See below.

Heat treatment
Out-of-flatness of the flapper valves after tumbling of the edges can be a sign of an unsatisfactory tumbling operation. In such cases, stress relieving of the valves, before tumbling, may solve the problem. Tumbling can then be expected to give the beneficial compressive stresses as described above.

Stress relieving should be carried out in a fixture and with a holding time of 30–60 minutes. The temperature should not exceed 235°C (450°F) for Sandvik 20C. For Sandvik 7C27Mo2 and Sandvik Hiflex the maximum temperature is 350°C (660°F).

Heat treatment

![Heat treatment diagram](image)

Examples of edge profiles after different tumbling times.

![Tumbling diagram](image)

The two diagrams show the effect of surface treatment on the reversed bending and impact fatigue strength of Sandvik 7C27Mo2 and Sandvik Hiflex. In both cases Sandvik Hiflex exhibits the most positive effect.

During and after the tumbling operation, components, especially those made of carbon steel, must be adequately protected against rust, which would otherwise considerably reduce their fatigue strength. A pH regulator containing a rust inhibitor can be used, or else a rust inhibitor can be added separately. The components must be thoroughly cleaned and rinsed after tumbling, and then oiled.
Sandvik Group
The Sandvik Group is a global high technology enterprise
with 47,000 employees in 130 countries. Sandvik’s opera-
tions are concentrated on three core businesses: Sandvik
Tooling, Sandvik Mining and Construction and Sandvik
Materials Technology – areas in which the group holds
leading global positions in selected niches.

Sandvik Materials Technology
Sandvik Materials Technology is a world-leading manufac-
turer of high value-added products in advanced stainless
steels, special alloys, metallic and ceramic resistance materi-
als, as well as medical implants and process plants.

Quality Assurance
Sandvik Materials Technology has Quality Management
Systems approved by internationally recognized organiza-
tions. We hold for example: the ASME Quality Systems
Certificate as a Materials Organization, approval to ISO
9001, ISO/TS 16949, ISO 17025, and PED 97/23/EC, as well
as product approvals from TÜV, JIS and Lloyd's Register.

Environment, Health & Safety
Environmental awareness, health and safety are integral
parts of our business and are at the forefront of all activities
within our operation. We hold ISO (14001) and OHSAS
18001 approvals.

Integrated production for consistent properties
With our own metallurgy and strip production, we control the whole
production chain from steel melt to the finished product, using the latest,
most reliable technology.

Steel melting is a high-tech process
The melting of flapper valve steel is a precise opera-
tion, where Sandvik’s leading metallurgy, inclusion
and trace-element technology comes into its own. By
careful selection of the raw material and balancing
the production process, a very clean steel can be
achieved. This know-how leads to materials, which
offer the best possible performance.

The art of strip making
We have been in the flapper valve business since they
were first used, which means that we have learned the
art of rolling thin strip with excellent surfaces and
perfect shape. Our strip steel also has close dimen-
sional tolerances, a prerequisite for safe and efficient
functioning of valves.

A hardening process for optimum properties
Hardening and tempering of flapper valve steel is car-
ried out on specially built, modern production lines.
The hardening process can be closely controlled
throughout in order to give a suitable microstructure,
resulting in optimum tensile and fatigue strength.
The strip also receives a high degree of flatness – a
guarantee of tight valves. An excellent surface finish
is also achieved by in-line polishing.

We are where you need us to be
An efficient communications and logistical network makes
Sandvik Materials Technology an easy partner to do
business with. Around the clock, advanced IT systems link
our salesmen, order clerks, stock controllers, marketing
support personnel and distributors to provide global
availability of our products. The whole world is
our home market. And we can share technical
and commercial information with our customers,
using the latest web techniques. Please visit us
on our website: www.smt.sandvik.com