High Efficiency Mitsubishi Centrifugal Compressors and Steam Turbines for Large Methanol and DME Plants

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Methanol plants have been steadily increasing in size in recent years as a means of reducing unit production costs, or in other words, improving energy efficiency. In order to meet such needs of plant owners, Mitsubishi Heavy Industries, Ltd. (MHI) has developed technologies for high efficiency, large centrifugal compressors and steam turbines for large plants. In this paper, some experience of applications for these compressors and steam turbines are introduced, and the compressors and steam turbines for larger plants are proposed. Further more, these MHI compressors and steam turbines can handle DME (dimethyl ether) plants, the latest, because they have been developed using extensive experience and technologies, acquired over the years through the manufacture of conventional methanol plant equipment.

1. Introduction

In recent years, the capacities of methanol plants have increased from approximately 1 500 tons/day before the 1970's to the present 2 500 tons/day. Plans are currently being made to build plants with capacities of 5 000 to 7 000 tons/day. **Fig. 1** shows this increase in the capacity of methanol plants. The scale of DME plants, on the other hand, has been tending to increase further since these plants create more methanol as an intermediate product than conventional methanol plants.

2. Plant process and applicable centrifugal compressors

2.1 Methanol plants

The main centrifugal compressors used in methanol plants consist of:

(1) Synthesis gas compressors,
(2) Circulator compressors, and
(3) Natural gas compressors.

In a methanol plant, natural gas is mixed with steam and CO_2, at an appropriate mixing ratio, to form synthesis gas. The gas is pressurized by a synthesis gas compressor to approximately 100 atm, which then passes through a catalyst layer at 250 to 400°C in a reactor, where a methanol synthesis reaction takes place.

The natural gas compressor is a low-pressure compressor and is used when pressurization is required to feed natural gas to a reformer.

MHI usually combines synthesis gas and circulator compressor in one train. **Fig. 2** shows the configuration of the main equipment in a typical methanol plant.

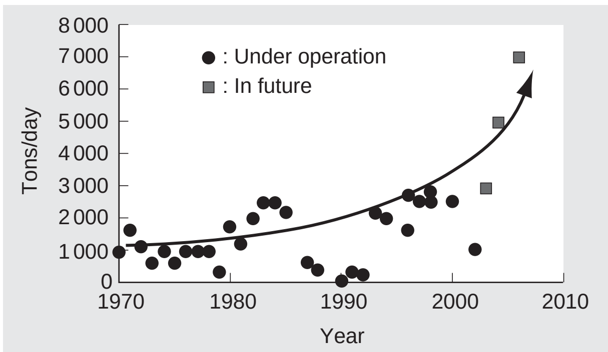

Fig. 1 Overall shift in capacities of methanol plants
This figure shows the steady shift in the capacities of methanol plants in which the size of these plants are increasing year by year.

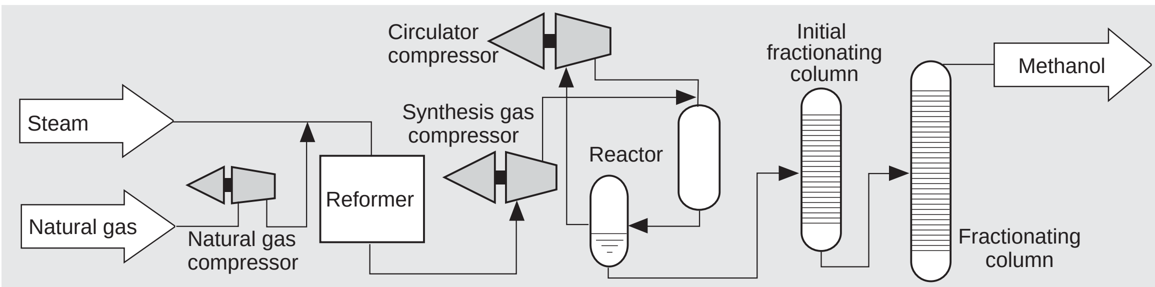

Fig. 2 Configuration of the main equipment in a typical methanol plant This diagram shows the configuration of the main equipment in a methanol plant and the location where the compressor and steam turbine train is installed.

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The synthesis gas compressor is made up of one LP (Low pressure) and one HP (high-pressure) casing, and the circulator compressor is combined with the HP synthesis gas compressor in a single casing. Both the LP and HP synthesis compressors are a multi-stage barrel type. **Fig. 3** shows a synthesis gas compressor for a 2 500 tons/day methanol plant.

MHI has made great steps in improving the maintainability of the equipment by applying a double end shaft drive design. In this design, the LP and HP synthesis gas compressors are positioned either end of the steam turbine.

As the plants become ever larger, the size of the synthesis gas and circulator compressors is also increased. It is therefore necessary to apply a high-pressure, large-sized centrifugal compressor for these plants.

Fig. 4 shows the configuration of a steam turbine driven synthesis gas compressor train selected for a 7 000 tons/day large methanol plant. As the capacity increases, so does the equipment size, and therefore the compressor impellers and steam turbine blades. Such plant capacity increases cause technical problems when designing high-load, high-efficiency equipment. However, MHI has confirmed that it is fully capable of supplying centrifugal compressor/steam turbine trains to meet the requirements of such plants by applying technologies that support an increase in size. These technologies and capabilities are briefly described below.

2.2 DME plants

DME (Dimethyl ether) is receiving attention as a new energy source and a new clean fuel that does not produce sulfur oxides or soot, even when burned. Further more, the amount of nitrogen oxides emitted are significantly less than those of fossil fuels. These beneficial qualities have resulted in much attention being focused on DME, as a national policy.

In the DME plants now being studied for industrial application, an indirect method is used to synthesize DME by dehydration of the methanol synthesized in the methanol plant, as outlined in section 2.1 above. In this case, the compressor technologies used in methanol plants can be applied to DME plants. The size of the plants is further increased compared with conventional methanol plants in order to produce DME in addition to the methanol. Accordingly, the technologies that are applied to large methanol plants also need to be applied to other equipment used in the plants such as the centrifugal compressors and steam turbines.

Studies are also currently under way to design plants to produce DME directly by synthesizing hydrogen with CO_2. With respect to the use of DME, MHI actively involves all processes of the manufacture, transport, storage, and utilization of DME, and is proactively engaged in activities that promote the utilization of new energy and environmental protection.

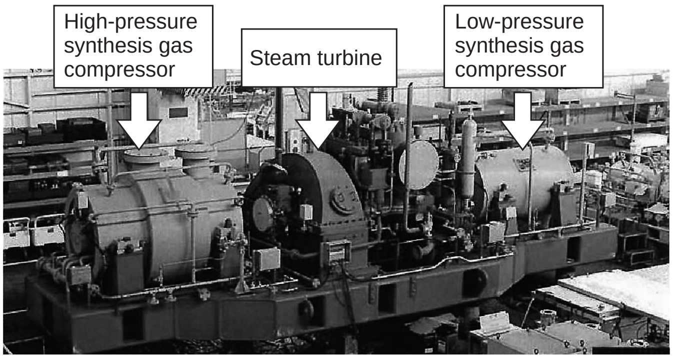

Fig. 3 Synthesis gas compressor train for a 2 500 tons/day methanol plant (overall length of the equipment is 9.0 m)
This photo shows an example of a synthesis gas compressor train installed in a 2,500 tons/day methanol plant.

Compressor rated speed	(rpm)	7 800
Turbine rated power	(kW)	53 000
Compressor suction flow	(Am^3/h)	29 600
Compressor discharge pressure	(ata)	108

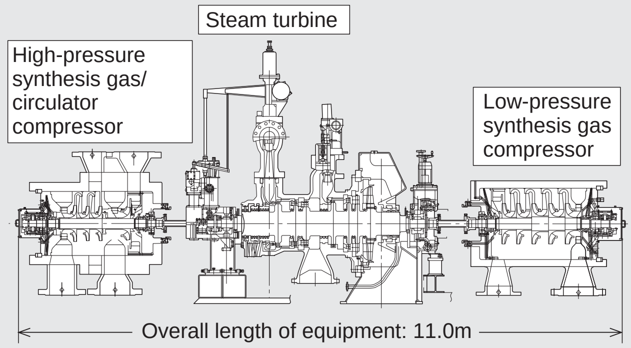

Fig. 4 Synthesis gas compressor train for a 7 000 tons/day methanol plant
This diagram shows the synthesis gas compressor train for a future 7 000 tons/day large plant proposed by MHI, together with its specifications.

3. Technologies for supporting the increase in the size of plants

3.1 Technologies for increasing efficiency

As the size of plants increases, the efficiencies of the centrifugal compressors have a greater affect on plant operating costs than before. To address this problem, the efficiency of large volume flow impellers applied in synthetic gas compressors, was increased by 1% more than before.

3.2 Technologies for increasing capacity

(1) Impellers with high pressure coefficients

In order to handle increased compressor volume flows, resulting from the increase in the size of plants, a high-efficiency, large volume flow impeller must be applied. But a large volume flow tends to require bigger impeller to accommodate large volume flow. Since an increase in the bearing span by bigger impellers can lead to unstable vibration of the rotor, it is preferable to reduce the number of impeller stages to shorten the bearing span. If not, the operating speed must be decreased to maintain rotor stability.

For this purpose, impellers with a high pressure coefficient are applied to reduce the number of impeller stages and achieve a much rigid rotor with excellent stability.

Fig. 5 shows a comparison between the pressure coefficient of a conventional impeller and that of an impeller with a high pressure coefficient. The pressure coefficient is increased by 10 % at the design flow point of the impeller.

(2) Impeller with increased boss diameter

The boss diameter of high pressure coefficient impellers is increased, and the shaft diameter on which the impeller is shrink fitted can therefore be increased, to achieve enough rotor stability.

3.3 Technologies for stabilizing the shaft

During the operation of a centrifugal compressor, a rotor exciting force and a damping force act on the rotor.

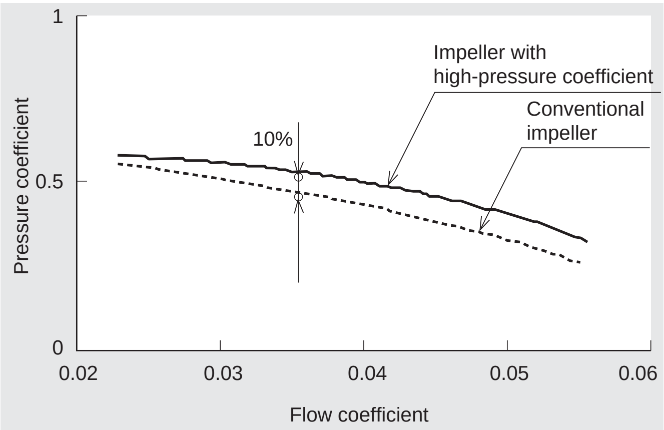

Fig. 5 Comparison of pressure coefficients between a high pressure coefficient impeller and a conventional impeller
The graph shows that the pressure coefficient of a high pressure coefficient impeller is 10% greater than that of a conventional impeller.

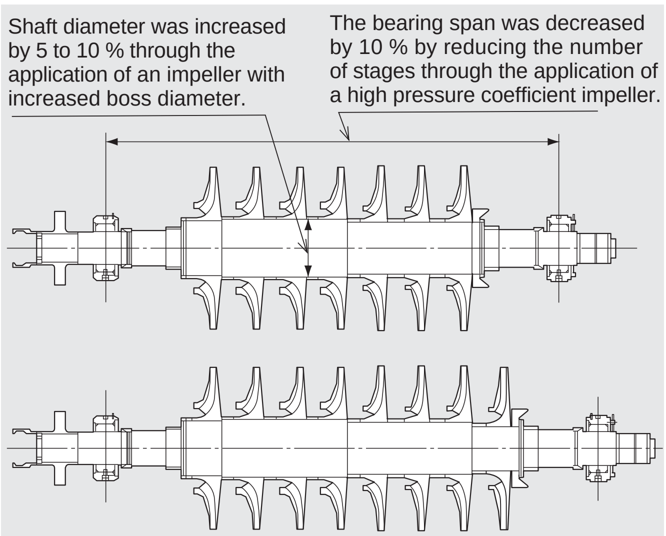

Fig. 6 Comparison of a rotor to which technologies for increasing capacity have been applied (the upper figure) and a conventional rotor (the lower figure)
The bearing span in the modified rotor was reduced by 10 %, and the shaft diameter was increased by 5 to 10 %. The rotor has a high rigidity for large compressors.

When the exciting force is greater than the damping force, the rotor becomes unstable.

In addition to applying MHI's conventional exciting force reducing mechanism (swirl canceller) and damping force increasing mechanism (overhang damper), the bearing span is shortened and the shaft diameter increased, as noted in sections 3.2 (1) and (2) above, in order to increase the rotor rigidity thereby achieving excellent rotor stability. A comparison of this modified rotor and a conventional rotor is shown in **Fig. 6**. The bearing span was reduced by 10 %, and the shaft diameter at the impeller shrink-fitted section was increased by 5 to 10 % resulting in a dramatic increase in rotor rigidity.

4. High efficiency steam turbines for large methanol plants and DME plants

Large capacity compressors for large plants require more driving power, therefore, the rated power of the steam turbines must increase. Many turbine manufacturers have previously applied double-flow type turbines for these large capacity steam turbine applications. However, MHI has applied single flow steam turbines in which long blades are used for large volume flow. By applying this single flow type turbine, MHI has been able to drastically reduce pressure losses in the steam flow passages to levels less than that in the double flow type turbines while also increasing efficiency. Another benefit is that the size of the turbine could also be reduced. This merit becomes significant for plant owners as plants increase in size.

MHI has developed a 250 mm blade that can cover a high speed, large volume flow range, not covered by conventional blades, and has applied it as a single flow, large volume flow blade, for use in large plants. These blades can easily handle even larger plants, which may be built in the future. **Fig. 7** shows a view of the 250 mm blades. **Fig. 8** shows the applicable range of these large volume flow blades.

Fig. 7 General view of a 250 mm long blade
This image shows the general view of 250 mm long blades.

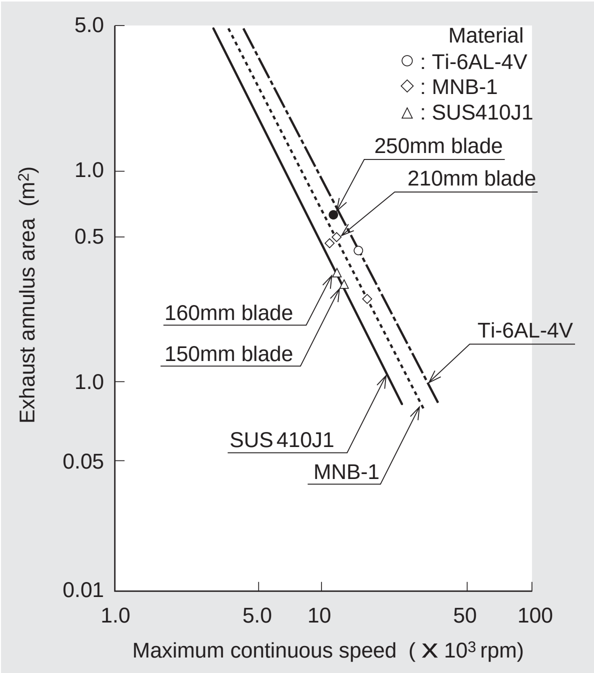

Fig. 8 Turbine blade for synthesis gas compressor drive
This graph shows that a newly developed titanium alloy 250 mm blade has an exhaust annulus area larger than that of conventional blades, which makes it possible for application in a large capacity range.

5. Production experience

MHI can manufacture and supply high efficiency centrifugal compressors and compressor drive steam turbines, which are capable of handling the increasing size of methanol plants and DME plants, all designed and manufactured in the same MHI factory, under the same high level quality control system. In addition, shop string test for the compressors and steam turbines can be performed in the same factory. **Fig. 9** shows such a shop test on a steam turbine driven centrifugal compressor train. **Fig. 10** shows a similar compressor train in operation on site.

5.1 Test results of aerodynamic performance

Aerodynamic performance tests of synthesis gas, circulator, and natural gas compressors, used in a 2 500 tons/day methanol plant, were carried out under the witness of the plant owners. The results verified the high performance level of these high efficiency compressors.

5.2 Results of mechanical performance tests

Mechanical performance tests of the synthesis gas, circulator, and natural gas compressors, used in a 2 500 tons/day methanol plant were carried out under the witness of the plant owners. Measured values obtained for vibration in the bearings were 15 μ m or less for the centrifugal compressors and 10 μ m or less for the steam turbines. These values are very small compared to the limit value of 25.4 μ m specified by API (American Petroleum Institute), and indicate excellent operational stability.

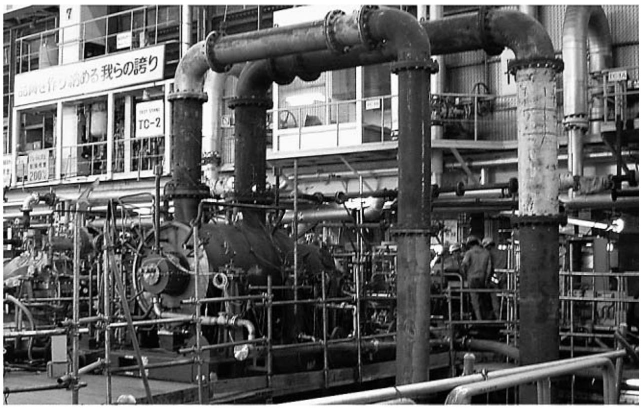

Fig. 9 Witness test in factory for compressors in a 2 500 tons/day methanol plant
This photo shows the compressors shop tested for a 2 500 tons/day plant.

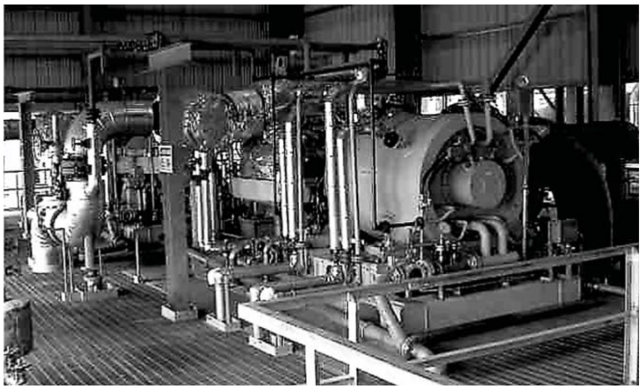

Fig. 10 On site operation of compressors and steam turbines at a 2 500 tons/day methanol plant
This photo shows the compressors and steam turbines in operation at a 2 500 tons/day plant.

6. Conclusion

This paper has given a brief introduction to the technological work being undertaken by MHI to develop large capacity and high efficiency centrifugal compressors and steam turbines suitable for the present trend of the increasing capacity of methanol plants and DME plants.

The large capacity technologies introduced here are being applied to the centrifugal compressors and steam turbines produced by MHI to handle the requirements of the 7 000 tons/day methanol plants and DME plants that are currently at the planning stage of development.

References

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