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THE PROBLEMS OF AN INTERNAL DIAMETER FORMING IN THE PACKING ELEMENT OF BRUSH SEAL GTE

Анотація

У цій статті розглянуто різноманітні способи формування внутрішнього діаметру ущільнювального елементу (УЕ) щіткового ущільнення (ЩУ) ГТД, а також окреслено виникаючі проблеми при обробці зазначеними способами. Дослідження виконано на ЩУ, розроблених на підприємстві ГП "Івченко-Прогрес". Поряд із цим запропоновано метод формування та доведення внутрішнього діаметру УЕ при робочих умовах експлуатації ЩУ на спеціальній установці. Крім того, описано його переваги над іншими способами обробки.

Abstract

In this article various ways of an internal diameter forming in the packing element (PE) of brush seal (BS) GTE are considered; the arising problems during the processing have been observed as well. Investigations have been carried out using BS developed at the state enterprise "Ivchenko-Progress". Along with it is offered a method of using a special mounting for forming and accurate grinding of an internal diameter in the PE by exploitation of BS under its operating conditions. Besides, its advantages in comparison with other methods of processing are described.

Target setting and its relation with practical tasks

The brush seals had already become object of special attention and of studying in abroad research centers in the beginning of 1980. Brush seals having a higher efficiency are offered in modern aircraft engines as an alternative to labyrinth seals and have a number of advantages.

Today among domestic enterprises the state enterprise "Ivchenko-Progress" is actively developing brush seals. At our enterprise an engineering process of the packing element had already been developed and the set of brush seals for conducting of complex tests with it following installation to aeroengine had been produced. But the works for improvement of design and fabrication method of brush seal are carried out constantly. At present time one of the problems is forming of an internal diameter in the packing element (PE). As there are design issues by determination of assembly clearance, the tolerance of internal diameter, there is also technological issues by executions of these requirements. The quality of treatment of an internal diameter in the PE is the main parameter, affecting the flexibility and compliance of wires. In turn BS is capable to greatly reduce leakages in engine due to this behavior, and influence on metering characteristic, which serves as a criterion for estimate of seal's efficiency; it was observed in previous publications as well [1, 2].

Purpose

The purpose of this work is investigation of various ways of an internal diameter forming in the packing element (PE) of brush seal (BS) GTE. The task was set to achieve the purpose of selecting an optimal and efficient method of execution of a given operation, which will allow to obtain the best surface condition and parameters of engine's work.

Substance and results of research

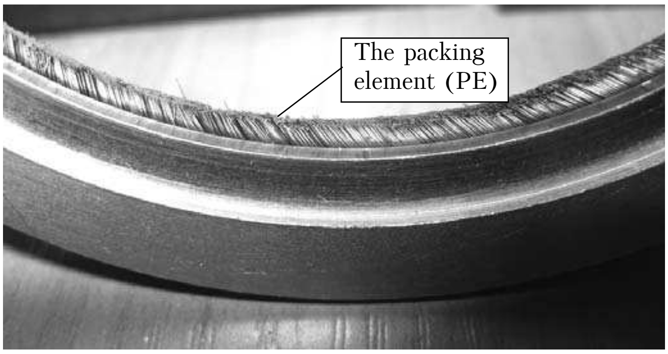
The seals had already been carried out in different design - technology executions in our enterprise (fig. 3). Testing seals were produced for work with arbor equal ∅90 mm. But today the task of an internal diameter forming remains in front of us and task about tolerance for diameter as well. Three variants of mating seal with shaft can be noted from our initial experience and long experience of foreign firms:

1. interference fit;
2. clearance and tolerance for internal diameter of BS equal (±0,12) mm;
3. clearance and close tolerance for internal diameter of BS equal (+0,05) mm;

However according to foreign literature [3, 4] an internal diameter of PE is grinded during engine's work, and steady gap between shaft and seal is fixed with time. It is evident on graphs (fig. 4).

Besides we have problems of accurate measurement of an internal diameter of PE because of gage probe touching a seal nap. The bristle pack is flexible technology system, and therefore this influences on accurate measurement (fig. 2).

We don't have enough experience to answer which of these three variants is the most efficient



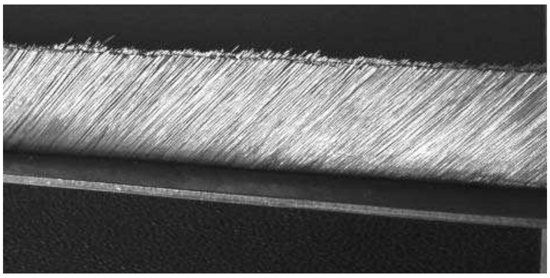
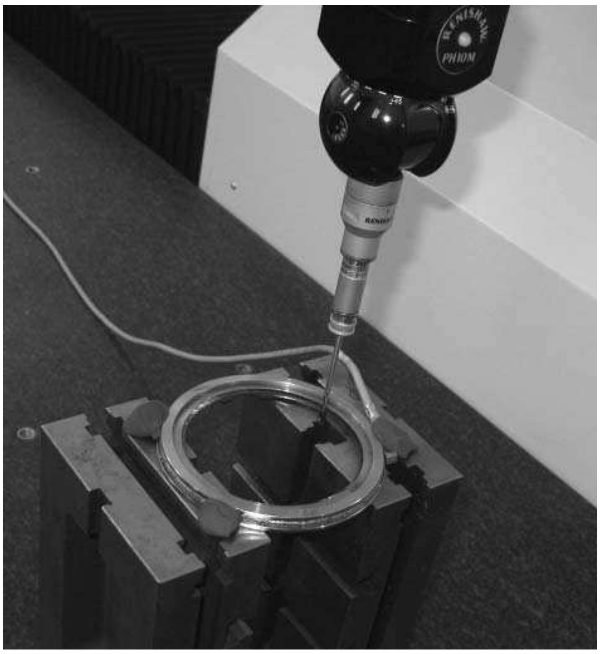


Fig. 1. The brush seal (BS) GTE on the left; the packing element (PE) before treatment on the right



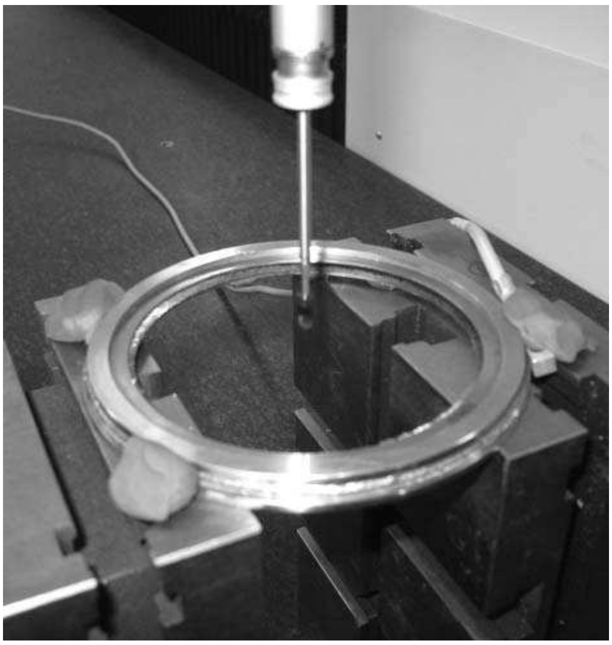
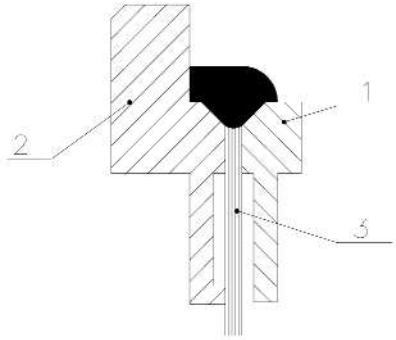


Fig. 2. The measurement of an internal diameter of PE on plate-measuring engine Wenzel



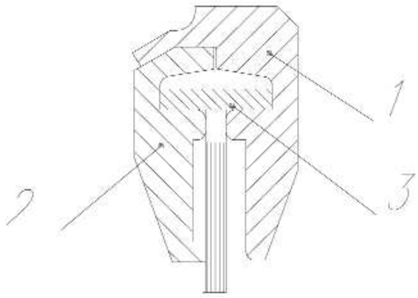
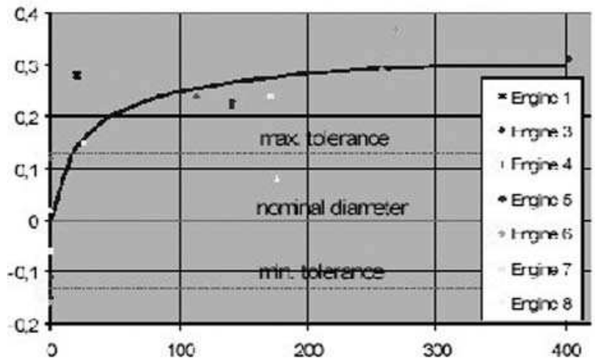


Fig. 3. Two variants of design BS:
a — welded construction, *b* — rolled construction, where 1 — cover plate, 2 — support plate, 3 — bristle pack (the packing element)



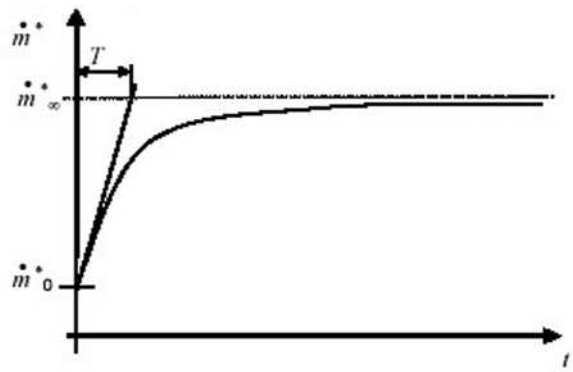


Fig. 4. Wear characteristic of BS wires and seal leakage over service life

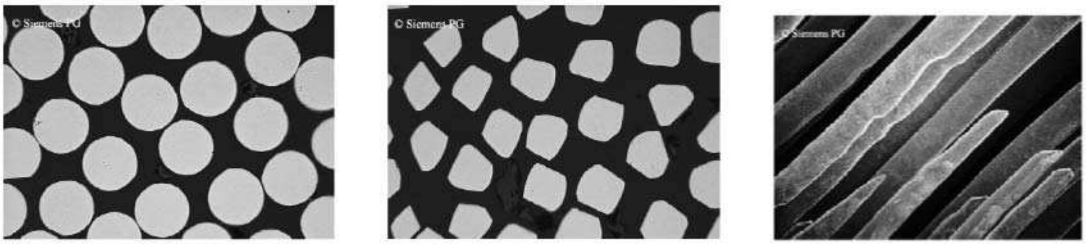
mating for forming of an internal diameter in the PE. However, we found an optimal method, which would allow the combination of three considered variants. Given method includes grinding of an internal diameter of bristle pack in a special rig. Its principle of operation is described below.

We were going on the way of manufacturing of brush seal with close tolerance for internal diameter of BS equal (+0,05) mm and its mounting with determinate assembly clearance. The clearance was rated, and depending on it was set the close tolerance for diameter. A few universal methods of treatment of an internal diameter were proposed under this scheme; and in accordance with them were developed engineering processes of its forming.

Complexity of nap treatment has arisen due to flexibility of system just as in its measuring operation. However all types of treatment were tested.

The following methods were investigated; each of them had advantages and disadvantages.

	Name of methods	Disadvantages	Advantages
1	Grinding of surface with an abrasive wheel with external diameter equal shaft diameter	Complexity of grinding of large BS diameter with an abrasive wheel.	The availability of an accurate internal diameter and high quality surface of processed nap.
2	Grinding of surface with an abrasive wheel with external diameter smaller than shaft diameter in free state of bristles of PE	Uneven treatment of an internal diameter because of high compliance of PE bristles (flexible technology system).	
3	Grinding of surface with an abrasive wheel with external diameter smaller than shaft diameter in clamped state of bristles of PE	- It is necessary to correct of grinding diameter given by draw; - The possibility to clamp the bristles of PE not in each construction.	- The flexible technology system during grinding; - The availability of surface high quality of processed nap.
4	Electric erosion machining of surface using electrical probe with planetary treatment up to required diameter	Limited external dimensions of bath of electrical-discharge machine AGITRON 2U, in case of manufacturing BS with an internal diameter larger than 300 mm.	The availability of an accurate internal diameter and high quality surface of processed nap.



a *b*

Fig. 5. Bristle pack cross section after 30 months (>20.000 hrs) of continuous service:
a — near the support plate; *b* — near the cover plate

Moreover special attention must be directed to long exploitation and durability of BS operation in gas-turbine engines as mentioned in previous articles [1, 2]. In addition to that it's necessary to pay attention at the work of an engine at the beginning and at the end in order to support the stable parameters of engine run. The problem of rotor and bristles radial wear exists, and especially under the conditions on varying duty. The bristle wear arise due to axial pressure drop across brush [3, p. 3]. According to figures 4 and 5 the conclusion was made that the brush seal is capable to adapt itself to the service conditions during life cycle. Fig. 4 presents a typical brush seal wear characteristic given as change of the inner bore diameter vs. running time.

The graph shows an average wear trend that is based upon mechanical inspection results of eight engines of a military project after extensive development and certification testing. The dotted lines depict the tolerance band for seals. The graph clearly indicates that after some running in, taking up to 50 hrs., the initial wear rate declines and levers off beyond 250 running hours to give constant seal performance. Brush seal wear may then be driven only by extreme flight maneuvers involving high g-loads or high gyro loads [4, p. 6].

Having analyzed the graphs, presented in foreign literature [3, 4], we offer to compensate the bristle initial wear, i.e. the part of curve from 0 till 150 hrs BS operation in plot by means of introduction of run-in PE before setting of detail in the engine. It will allow to eliminate about 75 percent of wear of bristle pack and mating with its arbor till exploitation of brush seals. In order to exclude this wear zone and to work with stable assembly clearance in engine, we proposed the method of an accurate grinding of inner bore diameter in the PE of BS GTD.

Given method concludes run-in of an internal diameter under operation pressure across seal and according to determinant metering characteristics. Besides it can be applied after processing of an inner diameter with universal methods. For this purpose at the enterprise was designed the special mounting, which in turn permits to perform not only an accurate grinding of an internal diameter, but as noted above compensate an initial wear of PE before setting of BS in an engine by way of using the shaft-imitator tool with the cutting properties. Produced mounting will enable to:

1. run-in of an internal diameter under operation pressure and rpm with determinant metering characteristics;
2. give a radial and axial displacement, imitating the cutting-in of rotor during aircraft evolution and thermal rotor expansion during engine work;
3. test the brush seal with an inner diameter up to 450 mm owing to readjustment of mounting;
4. fix and research behavior of bristle nap of PE under pressure;
5. investigate the brush seal in static and dynamic positions;
6. prevent damage of rotor (its wear and formation of groove equal width of PE) during its initial mating with brush seal;
7. determine the assembly clearance, obtained after established metering characteristics.

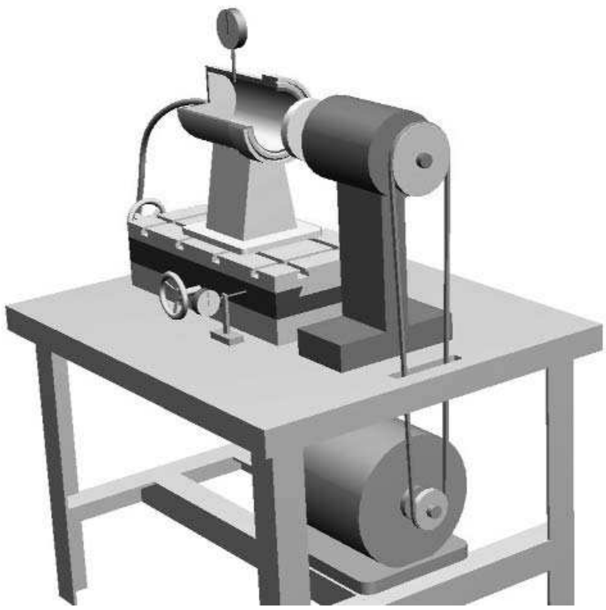


Fig. 6. Sketch of special mounting for accurate grinding of an internal diameter in the PE

Conclusion

In the course of conducted work were tested and investigated the following processing methods of an internal diameter in the PE of BS GTE:

- grinding of surface with an abrasive wheel with external diameter equal shaft diameter;
- grinding of surface with an abrasive wheel with external diameter smaller than shaft diameter in free state of bristles of PE;
- grinding of surface with an abrasive wheel with external diameter smaller than shaft diameter in clamped state of bristles of PE;
- electric erosion machining of surface using electrical probe with planetary treatment up to required diameter.

The considered methods can be applied depending on design-technological excursions of BS. However along with it had been offered a method of using a special mounting for forming and accurate grinding of an internal diameter in the PE by exploitation of BS under its operating conditions. It permits to compensate an initial wear of PE and mating with it shaft approximately first 150 hrs and install the stable gap between brush seal and rotor, determining the metering characteristic of seals in gas-turbine engines.

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