euspen's 20th International Conference & Exhibition, Geneva, CH, June 2020
www.euspen.eu

# Tool concept for structure rolling to improve tribologically stressed components

Torsten Schmidt[1], Jörg Schneider[1], Jan Edelmann[1]

[1]Fraunhofer Institute for Machine Tools and Forming Technology IWU, Chemnitz, Germany

jan.edelmann@iwu.fraunhofer.de

**Abstract**
Extensions of functional ranges and increases in efficiency are among the constant companions in automotive engineering as well as in machine tool industry. In most cases, increased performance requirements meet lower or constant component dimensions, whereby the functional surfaces are exposed to higher loads. These are often components subject to high tribological stress, such as friction bearings or cylinder liners. Against this background, these surfaces are often functionalized by coatings or microstructures in order to meet the increased requirements.
For surface micro structuring, a number of processes are known which differ in their suitability for specific applications and series production. Structure rolling offers great potential for the structuring of rotationally symmetric components. With this process the positive structure of the embossing roller is replicated onto the workpiece surface under a defined contact force. This comparatively simple method of structure generation enables a fast and flexible process for transferring different structural geometries to extensive component surfaces.

The publication focuses on structure rolling as efficient manufacturing technology. Within the scope of several research projects, various tool concepts have been implemented and advanced, whereby the current tool design is presented and discussed. In addition, the dimensioning and production of the positive structure on the embossing roller by means of laser structuring is described. The potentials of the process are shown by means of an application-oriented example.

Machining, Rolling, Tribology, Surface modification

## 1. Motivation

As a result of increasing power density in technical systems, the friction and wear behaviour of the components contained in them increases.This requires the use of new materials, coatings and technologies in order to maintain the product life and to implement the new features economically in the system. The microstructuring of technical surfaces is one way to positively influence the hydrodynamic conditions in the tribosystem [1, 2]. The manufacturing process "structure rolling" was developed for the transfer of micro-structures on primarily rotationally symmetrical components.

The surface microstructure is transferred to the workpiece by using a tool with an integrated microstructured roller. The advantages of this process compared to laser structuring lies in the comparatively fast transfer of the microstructures to the component functional areas. Low process and tool costs and the simple adaptability of the process to existing process chains in series production are further benefits. Due to the process, care must be taken to avoid throw-ups during structural rolling so that the tribologically effective surfaces are not impaired. However, this aspect must also be taken into account when structuring with a short-pulse laser [3].

## 2. Tool for finishing of small inner diameters

Especially in the area of burnishing and deep rolling, single-roller tools for machining outer diameters are known, which can be modified for roller burnishing with structures. For the internal machining of rotationally symmetrical components, a new tool concept has to be considered, since available tools are only suitable for machining large internal diameters of $D_i > 100$ mm. The aim of the R&D work was to develop a spring-loaded tool concept for structuring inner diameters down to $D_i > 25$ mm. The main challenges here lie in the overall stiffness of the tool structure, the reliable adjustment of the embossing force and the radially elastic mounting of the structure roller. Especially when producing structural geometries with a structural depth in the single-digit micrometer range, it is necessary to provide a radially elastic bearing to compensate for concentricity deviations of the structured roller bearing and the concentricity tolerances of the component in order to achieve a homogeneous structural depth.

### *2.1. Embossing roller tool concept*

Figure 1 shows the structure of the new spring-loaded tool concept for structuring inner diameters $D_i > 25$ mm such as journal bearings.

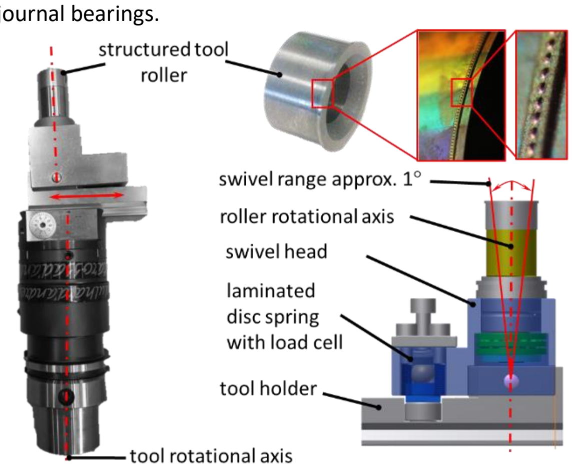


**Figure 1.** Embossing roller tool with load cell and structured roller

This tool concept is currently suitable for embossing microstructure diameter dimensions Ds <= 150 µm with a depth of Ts <= 30 µm and a textured area ratio TA <= 35 %. Disc springs of spring steel according to DIN 2093 are used in the tool. When the embossing structural dimensions will be larger, only smaller structural depths can be achieved. Therefore the spring force and possibly the rigidity of the tool structure must be increased.

### *2.2. Roller tool manufacturing*

The structure rollers are manufactured by means of ultra-short pulse laser ablation. With this process the positive shape of the surface microstructure is fabricated by material removal from a hardened steel or hard metal roller without any reworking needed. The decisive factor here is the type of geometry specification and the choice of the removal strategy. The geometry can be specified as a 2D layer specification for simple shapes or as 3D structure file for complex geometries. In the removal strategy can be differenced between single segment removal or single structural layer removal. In the first case, the structures are finished down to the depth before the next segment is started. With the single structural layer removal, all structures distributed around the circumference are divided into layers and processed layer by layer. The number of tool revolutions corresponds to the number of layers. With this method, it is possible to avoid steps between individual segments, but the edge steepness or accuracy of the structure is reduced.

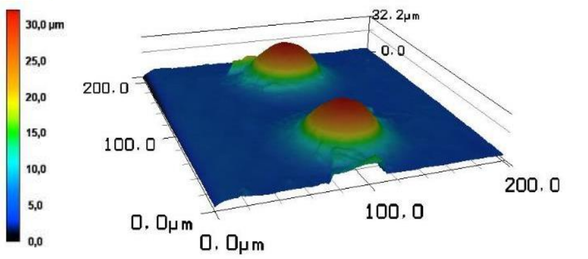


**Figure 2.** Microstructure D = 60 µm on a carbide roller tool

Figure 2 shows two optically measured microstructures on the roller tool with a structure diameter of approx. Ds = 55 µm and a structure height of Hs = 27 µm, which were produced by using a single segment removal strategy.

### *2.3 Design of the structure roller embossing process*

In addition to the diameter ratio of the structural roller to the inner diameter of the workpiece, the feed, the infeed and the resulting spring force are necessary for the design of the process. The diameter ratio of the tool to the workpiece can be used to determine the microstructures in contact, which represent the dimension for the area to be formed.The degree of surface coverage can be varied with the change of the feed in the axial direction. In the circumferential direction the degree of coverage is determined by the dimensions of the structural roller. Due to the infeed of the tool the swivel head will be tilted and puts strain on the laminated disc spring. Its reaction force must be higher than the force required for the forming process so that the structures can be transferred from the tool roller to the workpiece. The spring characteristic curve of the disc spring assemblies should have a degressive curve in order to create a homogeneous structural depth and to compensate possible workpiece tolerances.

## 3. Evaluation of the structure rolling tool

The functional proof of the implemented structure rolling tool is demonstrated by an application-oriented example. For this purpose a workpieces made of a bronze alloy and an inner diameter Di = 30 mm were structured with the structural parameters shown in Table 1. Due to the structural geometry, structural surface areas vary by a factor of 4 at a constant embossing force. Looking at the resulting structural depth of both variants, they are about 7 times different.Therefore, the focus for the future research will be on determining the necessary embossing forces for replicating the microstructures at defined depths. This will be nessecary to achieve a controllable embossing process.

**Table 1.** Comparative structure and parameter analysis

| Parameters | Structure 1 | Structure 2 |
|---|---|---|
| Diameter | 100 µm | 350 µm |
| Solidity ratio | 20 % | 30 % |
| Structure in contact | 12.9 | 4.5 |
| Structured area | 0.10132 mm² | 0.43295 mm² |
| Structured area ratio | 100 % | 427.3 % |
| Embossing force | 423 N | 423 N |
| Depth of embossed structure | 22 µm | 3 µm |

Figure 3 shows an optically measured section of structure 2 in Table 1, which shows clear burr in the direction of tool movement. This needs to be minimized or eliminated in further investigations. More experimental results will be represented in future after a wholistic tool experimentation.

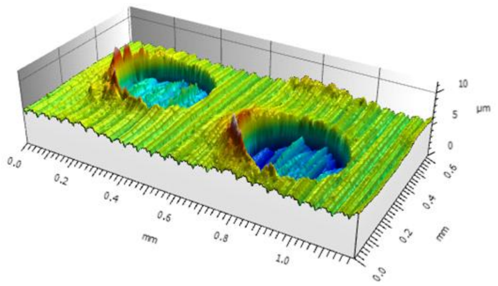


**Figure 3.** Embossed microstructure D = 350 µm

## 4. Conclusion

A tool concept for structural roller embossing of microstructures for small inner diameters was presented in this paper. The functionality of the tool and the fabrication of the structure rollers as well as the process conditions were discussed. Finally, the function of the tool was presented by an application-oriented example, and further research needs for the future were identified.

The IGF project (Nr. 20138) of the Research Community for drive technology (FVA), Lyoner Str. 18, 60528 Frankfurt/Main has been funded by the AiF within the programme for sponsorship by Industrial Joint Research (IGF) of the German Federal Ministry of Economic Affairs and Energy based on an enactment of the German Parliament.

## References

[1] Schubert A, Steinert P, Schmidt T and Hackert-Oschätzchen M, 2012, *Manufacturing of tribologically optimized surfaces for powertrain applications,* Key Engineering Materials, Vols. 523-524, pp 799-804

[2] Tala-Ighil N, Fillon M et al, 2011, *Effect of surface texture area on the performances of a hydrodynamic journal bearing*, Tribology International, Vol. 44

[3] Bliedtner J, Müller H, Barz A, 2013, *Lasermaterialbearbeitung – Grundlagen –Verfahren – Anwendungen – Beispiele*, Hanser Verlag, pp 173-179