Summary

A METHOD OF MINIMISATION OF THE BACKLASH IN GEAR TOOTH IN GEAR DRIVES

The machine industry uses various types if gears for drives, generally classified as either open or closed. Enclosed gears are constantly being improved in terms of their accuracy of movement, while open gears such as rack and pinion have reached a point in their development where no further improvements can be easily obtained. Despite this shortcoming, the rack and pinion drives are widely used in cutting machines, in particular drilling and milling machines. In these drives, there is an intra-tooth play, also termed backlash, that being defined as the difference between the space between two consecutive teeth and the space occupied by a single tooth, which is necessary to ensure smooth meshing of teeth hence unobstructed gear drive movement. However, while necessary, the intra-tooth play can have an adverse effect on the positioning of the machine tool. To overcome this issue, a second pinion can be introduced to the system. A solution based on two pinions was previously used by some German, Japanese and Thai companies. However, the solution presented in this thesis is different to those previously proposed, as evidenced by the patent granted by the Polish Patent Office under the number P.431714.

In general, toothed rails, also known as racks, which can be several metres long, are usually made with helical teeth and so are the pinions. Based on geometrical relationships, it is easy to determine characteristic properties of the rack and pinion arrangement, including the teeth size and the corresponding gear backlash. Another important issue in the design of rack and pinion gear are the forces which occur at the teeth interfaces due to the gear operation.

The aim of the innovation presented in this thesis was to find a solution to the rack and pinion gear involving the second pinion, such as to minimise the gear backlash in SKODA WD200B boring and milling machine. To this end, the first, i.e. original, pinion is rigidly fixed within the gear, while the second, i.e. added, pinion is mounted pendulously and pulled against the rack. The principle of operation of the assembly is that when one pinion is in contact with the rack at one side of the rack's teeth, the other pinion is contact with the rack at the other side of the rack's teeth. In this way, there pinions never really need to overcome the backlash, hence improving the

controllability, in particular the positioning, of the machine. The construction of the second pinion needs to be rigid enough to carry the load associated with the operation of the machine's tool and its passage along the guides. The drive of the second pinion is provided by a chain transmission from the first pinion under sufficient tension to ensure play-free movement. The second pinion's teeth are pressed against the rack using hydraulic actuators.

Prior to the implementation of the second pinion system, the errors in positioning of the machine measured with laser-based instruments were approximately 0,3 to 0,4 mm. The errors measured with the same instruments right after the installation of the second pinion system were approximately 0,1 mm, which indicates a significant improvement in the context of controllability of the machine and precision of the produced components. Furthermore, the introduction of the second pinion system enabled a numerical control system to be implemented within SKODA WD200B, which was originally not an option. Therefore, all in all, the introduced modifications extended the machining capabilities, including accurate turning and milling operations, at a fraction of the cost associated with the purchase of a new machine. The proposed solution is not specific to the particular problem that had to be solved, but it is fully adaptable for implementation in similar machines.

In addition to the main achievement presented in this thesis, other original solutions are also described, albeit in lesser detail. These include a hydraulic cleaner for a laser cutter grate, a flanging machine for dished ends of cylindrical tanks, a water grate for oxy–acetylene and plasma cutting machines, a hydraulic bearing for large rotary tables, a BOXER–type straightening press, welding rotors for tanks of the mass of 40 and 80 tonnes, and a roller-based support for the rolled components.