Flexible Manufacturing and Automation

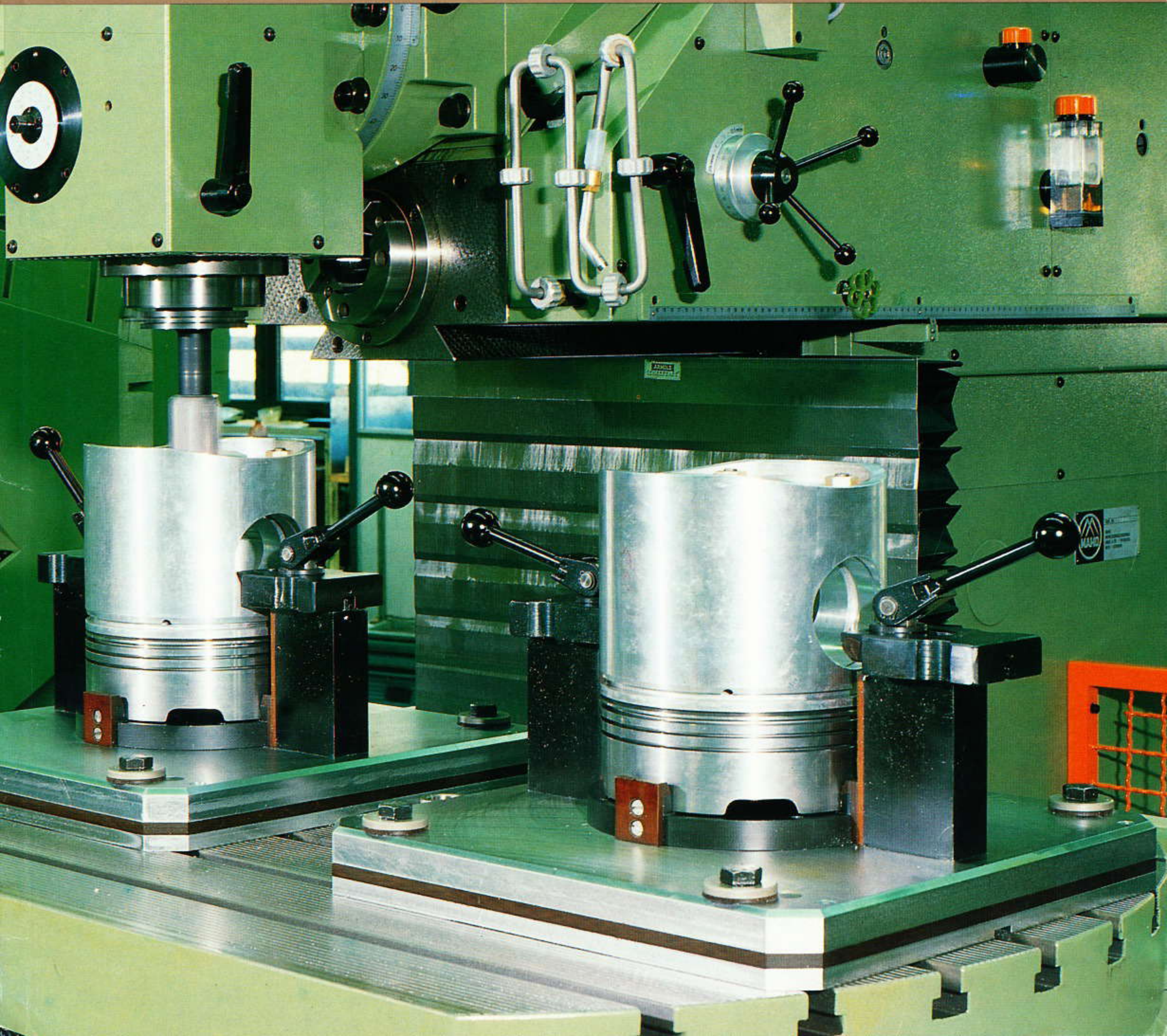
3-84

Industrial & Production Engineering

HANSER PUBLISHERS

A publication by Carl Hanser Verlag Munich

IPE INTERNATIONAL



Modern Quality Management in Practice

by H. H. Danzer, Graz, Austria

1 Actual Situation

The problems with which modern quality management is faced today are to be discussed from the angle of small- or medium-size series assemblies combined with a flexible and more diversified batch production, the requirements with which the finished product has to comply being just as strict as the ones that are currently applied within the automotive industry.

At Steyr-Daimler-Puch's works in Graz, we are at present manufacturing the all-terrain vehicle "G" for the Mercedes company (Fig. 1); shortly, the four-wheel drive version of the Volkswagen van will leave the assembly line in Graz, our PINZGAUER all-terrain vehicle is known throughout the world (Fig. 2), and finally, our sales of two-wheel vehicles are due. in the first line, to the traditionally high quality of our products.

We are thus in a situation which is by all means typical for medium-size enterprises: The quality level must comply, without any deficiencies, with client's specific expectations. On the other hand, however, the batch sizes are subject to considerable fluctuations due to the diversity of products and parts and the variety of models, and they are often small, thus causing that neither Production nor Quality Assurance are able to elaborate solutions which could be ideal from a management point of view.

The problem factors related to Quality Assurance's management function may be listed up in catchwords as follows: Increasing expectations in respect of the quality level on the customer's side in the middle of a ousting competition, tightening of legal stipulations and as a consequence, a trend towards more restricted design tolerances, a boom in the variety of models and too little time to simultaneously adapt modular concepts, an extremely high pressure for ratioanalization in order to survive on dwindling markets, and in connection with this, the obligation to enlargen tolerances, as well as finally, the pressure to reduce stocks and circulating assets, requiring as a consequence that batches be manufactured in sizes that are as small as possible, with reduced changeover times and a high rate of flexibility.

To express it in one single phrase: Product quality must be assured at a level that is rather higher than in previous days, at expenses that are lower than the ones incurred for this function in the past, while coordinating with scrupulous care the tolerance requirements that are in contrast with eachother, the production lot sizes becoming increasingly more diversified and smaller and the reaction times within one lot run extremely short.

These "exterior" difficulties are aggravated by the problems induced by quality assurance itself; these problems may be summarized, in a somewhat simplified manner, as follows: Efficiency is expected to be achieved by means of the application of statistical testing systems even beyond the limits of the practical applicability of such statistical methods. We are currently faced with dramatic changes in the field of measuring and evaluation techniques due to the gap between minimalized functional tolerances and the required high manufacturing tolerances. The problem of the petrified clichée of the role that is played by inspection and control takes us to the following question: Is it possible in Europe to shake off the imported "taylorist" ideas to the point of having the individual worker, adjuster or foreman assume once again full responsibility for achieving the required quality level? Following this picture of exterior and interior difficulties, we shall now try to point out a number of possible solutions.

Fig. 1. All-terrain vehicle Mercedes 300 GD

2 Limits of the applicability of statistical quality assurance methods

Even today, statistical quality control is often regarded as the one universal remedy suited to reduce quality assurance consts and always optionally applicable. And then, many people wonder just how one can succeed, by means of a sampling operation of an extremely limited extent and following exactly prescribed procedures, to find within a lot containing 2 per cent of defective parts exactly the two bad items from among the 100 elements assessed. However, this is exactly the situation in which we find ourselves if we try to determine what failure rate level could still be tolerable without causing serious trouble for subsequent manufacturing operations and how high the expenses may be that we are willing or able to accept for inspection purposes.

3 Incoming inspection

As far as the inspection of incoming goods is concerned, the identification of small failure rates by means of sampling systems as described, for example, in Mil Std 105 D based on AQL-values, cannot represent an efficient method of determining the acceptable quality limit, because either one would fall back on an inspection of almost every single item contained in the supplies, or – and this is what happens in most cases – the inspections carried out are a mere alibi. These are then often explained with the necessity of having identity inspections. However, quantity and identity inspections are not part of Quality Assurance tasks, but rather come into the field of Goods Acceptance.

Fig. 2. All-terrain vehicle Puch Pinzgauer

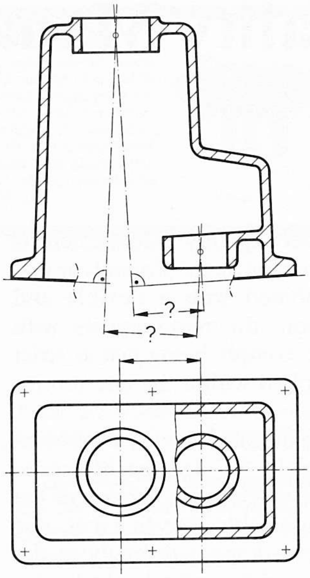


Fig. 3. Distance between boreholes in case the basis is not definitely determinable

The consequence within the framework of the inspection of incoming goods is rather simple: The quality of the goods supplied is as good as it has been provided for by the supplier. This is why, at an early stage already, that is before starting regular supplies and on the occasion of their initiation, we shall have to come to an agreement with the supplier and consolidate at his works and with his active collaboration the quality level in an appropriate way. The important aspect here is that we must be able to transform or assemble the materials supplied without any difficulties, but not that they were merely supplied. Of course, we shall have to check from time to time by means of quality audits whether any modifications have occurred in the meantime, and any complaints must immediately result in an improved coordination with the supplier, although the current series received should be fit to be transformed or assembled as they are supplied.

After long years efforts, we now finally reached the point in which, afterhaving carried out the supplier evaluation, the coordination and the original sample inspection, we are able to release already approximately fifty per cent of the parts supplied directly to Production, without submitting them to a quality inspection upon receipt.

4 Flexible batch production

The consequent conclusion in the case of flexible batch production is quite similar. In our case, the lots are manufactured often for such a short time only, that the command of processes by means of statistical methods is not feasible if only for the fact that the job is just not running long enough. The preliminary conditions underlying the achievement of an adequate quality level must therefore be created in time before and during the starting-off of production.

During the manufacturing process, the quality level may be efficiently and economically influenced only at the source, that is on the level of the individual worker or adjuster. This is where one can find out which one of the parts is not in line with all the others. Afterwards, it is very difficult to determine the quality of an item, as this can only be done by inspecting each single item and by checking each one of the possible characteristics once again. This quite usual procedure is very expensive, on the one hand, and from the management's point of view, it is also quite dangerous because of the demotivating effect it has on the staff working in Production, due to the fact that the responsibility for the achievement of the quality level devolves more and more from the worker upon Inspection at the end of the line, following the slogan: "Further on downstream, someone will inspect it anyway!

Statistical sampling methods, in any case, are not efficiently applicable for the purpose of assuring the quality of individually manufactured parts, of subassemblies or of batches – at least not under the conditions discussed earlier. We therefore have to reconsider our situation, a situation which resulted from many different – often optional – constraints. We have to abandon our traditional ideas about quality inspection and analyse the entire complex of processes involved with a view to the achievement of the required quality level and to quality assurance.

5 Coordination of tolerances

Following this discussion of the applicability of statistical sampling procedures, we shall now examine the announced changes in the field of measurement techniques and the assessment of the results obtained, in order to get to grips with this second pilar of quality management, too.

As mentioned earlier, there are currently two trends as regards design tolerances that are opposing one another. In order to comply with the increasingly high expectations of the customer which were caused by the ousting competition that is currently prevailing and which concern, more in particular, reliability and service life requirements, and because of the growing number of conditions that are to be fulfilled to the last detail when being engaged in interchangeable manufacture, function-oriented tolerances have to be restricted, that is reduced. Just think of the very clear-cut legal stipulations regarding maximum speed limits for motorized two-wheeled vehicles. On the other hand, the application of new, more efficient manufacturing procedures, where great importance is attached to reduced piece rates combined with short changeover times, nearly always gives rise to the necessity of expanding design tolerance limits. These two constraints – the necessity of restricting tolerances for the purpose of obtaining minimum functional dispersions, on the one hand, and the re-

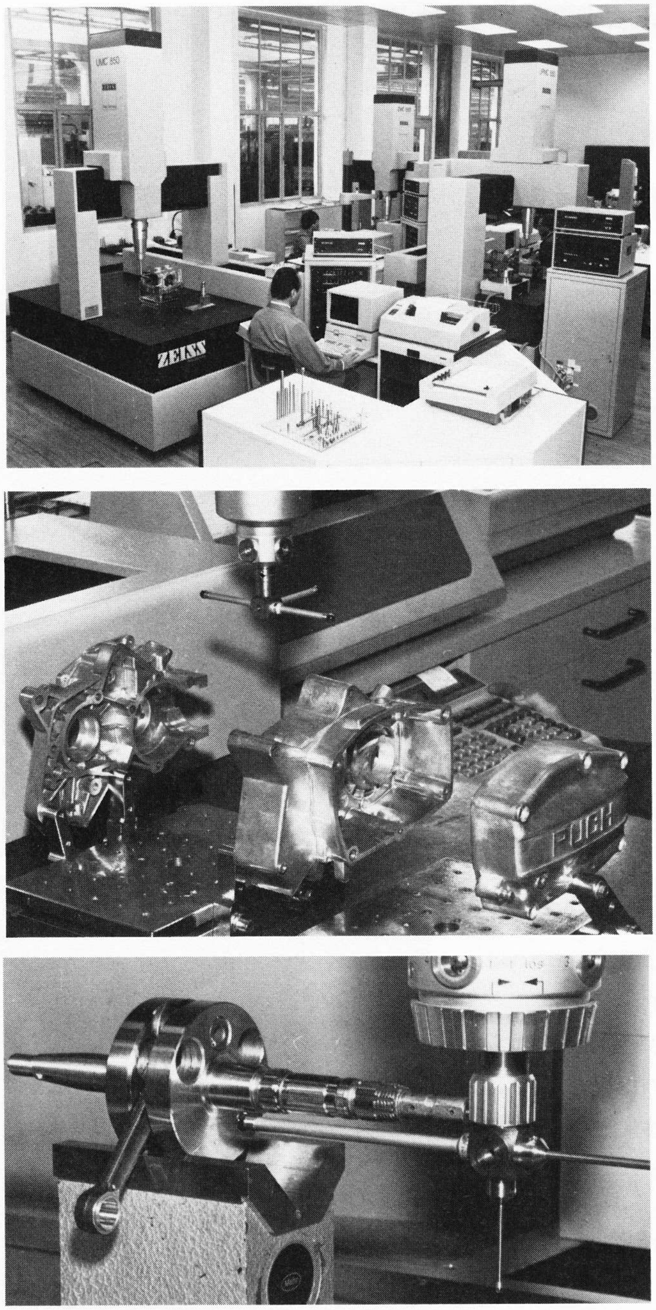


Fig. 4. Measuring room equipped with 3 D measuring centres used for coordinating the mechanical manufacturing of motor and transmission elements (top), CNC measurement of a casing on a 3D mesuring centre, including calculation and assessement of assembly functions (middle), measurement of a crankshaft on a 3D measuring centre, using functional surfaces (supports) as basis of the measurement (bottom)

quirement of expanding tolerances in order to be able to apply more efficient manufacturing processes on the other are accompanied by an unexpected third aspect which forces us to start our considerations all over again.

In the case of the highly rationalized manufacturing processes applied today, the characteristics of a more advanced order which have been more or less neglected up to the present and which contain, for example, shape or roughness parameters, come up to values which fall into the scope of the minimum measurement tolerances currently achievable.

Here are some examples to illustrate this statement: Fitted borings are executed with such powerful advances, that the roughness deepness reaches the order of magnitude of the dimensional tolerances which are very small. This is certainly not a nuisance, on the contrary, it functions extraordinarily well, although it is difficult to come to an objective statement as to what diameter the borehole actually has, considering the fact that different results are obtained from pneumatical and mechanical measurement procedures, and because the actual function, that is the type of adjustment of the fitting pin, is another variable.

Thus, for example, we analysed the bearing seats used in transmission casings, and we found that the deviations from the ideally shaped cylinder, that is oval form, conical form or others in the case of modern manufacturing processes present orders of magnitude that are similar to the minimum diameter dispersion that may be achieved.

The third example finally also questions the reliability of distance measurements: A transmission casing with two bearing boreholes is fit, for example, with one borehole situated near to the casing separating surface, whereas the second borehole is found at a distance of approximately 200 mm off this separating surface. The boring axes are parallel to each other and perpendicular to the separating surface (Fig. 3). For the desing engineer, the matter is quite simple. He drafts the borings in projection on the separating surface and indicates the distance. If, however, the separating surface is waved or if it has been warped during clamping or machining, how is the casing to be aligned in order to measure the boring distances? Even small deviations in the alignment will in this case lead to measuring very divergent boring distances, although the structural element remains the same.

It is just as dangerous to measure distances between surfaces or axes which – in the drawing, at least – are parallel to each other, but which in reality are simply not parallel enough to comply with the current high demands on distance tolerances.

We are thus faced with the same complex of problems as before: The characteristics considered up to now sufficiently precise and thus negligible influence the function of the individual component that is built by cost-optimized manufacture in the same way as the dimensional tolerances that have just been minimalized with lots of trouble. This phenomenon is bound to considerably complicate the balancing of tolerances which is the basis of efficient quality assurance, especially because of the fact that the quantifiable experiences related to the effects of these deviations are in most cases lacking and because even information on the prevailing actual situation is often gathered only by mere chance.

6 Examination of process efficiency instead of inspections as a basis of quality assurance

Looking at the matter from the angle of quality assurance as managerial task, the priority aspects within the previously discribed complex are certainly the registration and pursuit of the efficiency and capability of processes related to the individual manufacturing and assembly steps, as well as the assessment of the functional effects on the product; these aspects enjoy absolute preference to any routine part inspections.

In case part inspections and classification operations are imperatively required for the progress of the manufacturing

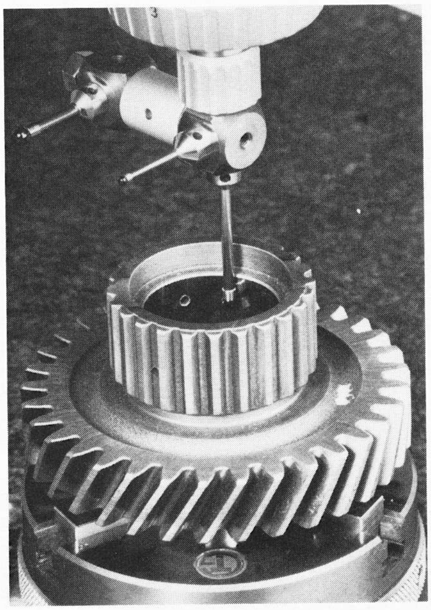


Fig. 5. Measurement of a gearwheel on a 3D measuring centre, using functional surfaces as basis of the measurement

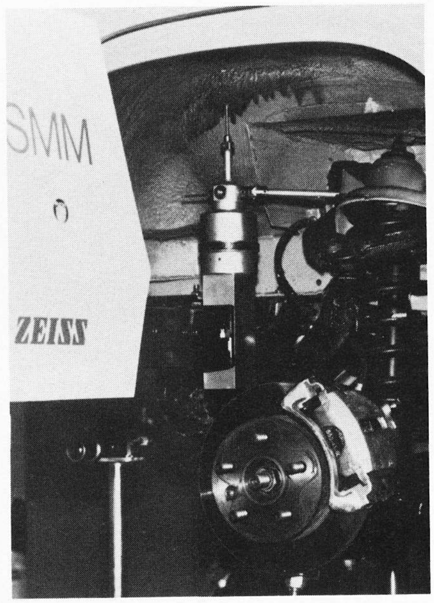


Fig. 6. Adjustment of the chassis geometry of a four wheel drive vehicle look at the probe showing up

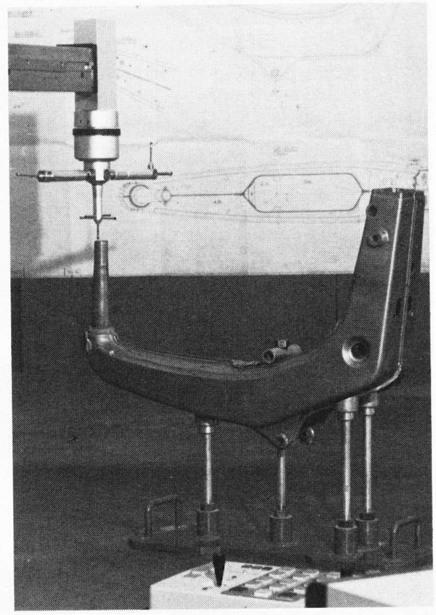


Fig. 8. Adjustment of the frame of a PUCH Moped MAXI PLUS in CNC mode

process, these control activities should be integrated into the production cycle in an optimal way, that is to say, that for disposition and optimization purposes they should be carried out by Production itself, especially if lot production periods are short.

The new task to be fulfilled by quality assurance personnel consists in registering the correlations between requirements, the efficiency and capability of machinery and processes and the effects on functionality, in making these data available to Production, Operations Scheduling and Engineering while continuously updating them, and in taking active steps regarding the settlement of all problems encountered, in order to ensure that all requirements, including expenses and time schedules, are adequately coordinated with real factors. At the end of these coordination activities, Production should be in a position to ensure in a sufficiently efficient way that the required quality level is achieved.

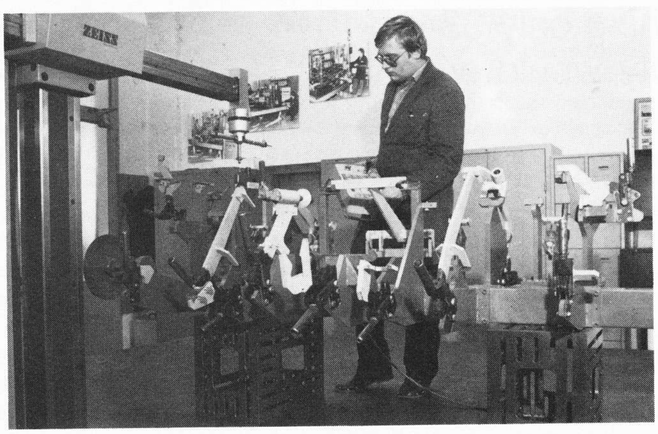


Fig. 7. Adjustment of welding devices of the front wall of our all-terrain PINZGAUER by means of 3D measurement procedures

Part-oriented specific inspection or measurement devices are ruled out as means for carrying out this job if only for the mere fact that it is impossible to register the above effects of an advanced order without incurring unreasonable expenses.

7 Measurement devices for geometrical characteristics

According to the experiences we gathered, the only devices that are suited to be used for the analyses mentioned before are 3D measuring machines. However, due caution appears to be recommended here. Two essential issues in particular must be carefully balanced, the measuring and assessment programmes, on the one hand, and the precision of the measuring machine, on the other. If, for example, it is necessary to measure the casing of a gearbox, it will not be sufficient to have at one's disposal a nice programme, including details relating to the shape and the position, in case the machine will define the shape of a circle less precisely than it is in reality. In such a case, the reproducible determination of a cylinder axis for the purpose of ensuring the orientation of the workpiece coordinate system is simply rendered impossible, and the results obtained by measurement will differ from one operation to the other, although precision appears to be high.

On the other hand, the programmes must be able to compress enormous amounts of data in such a way as to reduce them to entities that may be passed on to the staff in the workshop and to the development engineers without any further instructions for use as representative and self-explaining pieces of information. For examining and solving the problems described earlier, we have been using ZEISS 3D measuring centres for approximately five years now (Fig. 3 to 5).

7.1 Measurement of gearwheels

Even for the testing of toothed wheel works, which includes not only an inspection of the gear shape, but also the checking of the gearing position as compared with the other functional characteristics, we are applying a 3D mesuring centre (Fig. 5). Such a device allows for the carrying-out, during the measuring of the gearing, of any checks regarding the shape, the position and the lengths, while equally making it possible to establish coordinated evaluations, meaning that, for example, a toothed shaft may be measured in direct correlation with the bearing seat, without having to resort to the centre borehole as basis of the measurement, which will loose its function later on. This is impossible when using traditional gearing measuring machines (Fig. 6).

7.2 Adjustment of the carcass

The adjustment of the chassis, the frames, the car body elements, the complementary equipment and the accessory devices is equally carried out by means of a CNC 3D chassis measuring machine (Fig. 7 to 10).

8 Influences on the company and its operations

By means of a close cooperation with the supplier in the hardware and software field, we have been able to solve all the problems encountered to our full satisfaction, thus creating the following effect: Production is permanently and in a very detailed way informed about all its manufacturing processes. It is thus in a position to initiate preventive measures even before any problems occur on the quality level. Development gets the required feedback as regards which tolerances are actually respected during the manufacturing process and at which point problems are encountered. Being in possession of this information, Development is in most cases prepared to waive its own safety margin, to drop tolerances that are mainly motivated by fear, and to provide for tolerance values that are feasible and adequate from an economic and a functional point of view, tolerances upon the respect of which it may actually count, however.

After all, we are possibly the only manufacturers of two-wheeled vehicles who have been able, by adequate and graduated adjustment of parts, procedures and devices, to dispense with the so-called alignment of two-wheeler frames. We furthermore decided against using templates within our all-terrain vehicle assembly lines, and by applying chassis measurement operations at regular intervals, we have a permanent grip on the development of welding and assembling equipment precision values, thus being able once again to take appropriate measures even before intolerable deviations occur.

9 The achievement of the required quality level by Production in its own responsibility

After having discussed the limits of statistical quality control methods and the way leading from mere inspection and control operations to quality assurance by means of techniques that are suited to solve the problems we faced, we shall now come to the third issue that is important for modern quality management, that is to the question that was asked previously: Is it possible for Production to achieve the required quality level in its own responsibility, and how can this goal be accomplished? During the past years, we approached this complex of problems step by step and we found that under certain well-defined conditions which must absolutely be complied with, Production is actually prepared to take over the responsibility for the achievement of the quality level to the point of making it possible to dispense with any of the traditional inspection functions.

In fact, everyone is paid for doing his job adequately. Even timing schedules that underly wage scales comprise time portions designed to give the worker an occasion to check on the quality of his work. By principle, therefore, the correlation between quality responsibility and manufacturing department appears to be established anyhow. We only have to try to correct the "interdiction" of the worker in any questions related to quality, this taking away of responsability being mainly the result of downstream inspection services. For this reason, it is quite wrong to believe that the granting of additional quality premiums could represent an efficient way to attain one's ends.

10 Experiences made during the reorganisation phase

We adopted the following procedure: A moment had to be chosen in which due to the economic situation, radical measures could be easily and convincingly explained to all interested parties. We did not have to wait long for this moment to come, as this is the situation which unfortunately has been prevailing for several years already. Moreover, we had equipped our measurement rooms during previous years with devices of an adequately high quality, thus having at our disposal an instrumentation that was suited to objectively assess the manufacturing processes applied and to efficiently initiate remedial steps in case of problems occurring during manufacturing. Furthermore, the following issues have to be fulfilled whenever a reorganisation is aimed at:

The responsibility of the worker for the quality level to be obtained must be clearly defined. Appropriate mechanisms allowing to retrace any errors registered later on back to the one who is responsible for them must be introduced and should be known to anyone working at the place. On the other hand, it must just as well be possible to attribute any deserved praise to the right man or the right team, which is especially important when the work is organised in shifts.

Any checking activities which go beyond the time portions calculated for required self-control operations have to be integrated into the planning, in order to be duly justified to claim such checks. Any inspections or classification operations necessary within the framework of the manufacturing process for the purpose of accomplishing production are just as well part of this as the introduction of a subsequent rework service

Fig. 9. Verification of the adjustments on the PUCH MAXI PLUS

which is apt to carry out works that cannot be ensured by the individual worker in his own responsibility.

Subsidiary activities that had been taken over by quality control in its traditional form up to the present – such as piece quantity certifications, establishment of bills of shipment, etc. – must be reorganised in order to realise the most important issue:

Any inspection services controlling a specific manufacturing phase must be shut down for everybody to see. During the reorganisation phase, one of the essential tasks is to demolish clearly and suddenly the feeling that there is a quality safety net further on downstream, in order to make the worker realise the importance and seriousness of his quality function. The transition is thus not carried out gradually, but in one sudden cut which, however, has to be carefully prepared.

This preparation equally encompasses the coping with a discovery that is often bitter for Quality Assurance, namely the fact that the functional section "Quality Assurance" will require considerably less staff in the future than before, and that the supplementary expenses incurred in Production for the purpose of achieving the required quality level are less than one would expect.

Finally, one of the indispensable flanking measures is the introduction of an audit system designed to evaluate the quality level accomplished in autoresponsibility within the individual manufacturing sections, which includes the auditing of the final product.

The quality audits thus installed deal with the capability and reliability of processes and report on the efficiency of the quality assurance system.

After having assessed and classified the audit results, the priority issues are subject to problem-oriented examinations, and based on the information thus compiled, steps are taken – in cooperation with the concerned services – to coordinate drawings, process possibilities and functional effects.

We must be able to indicate to Production which measures are suited to ensure that the required quality level is accomplished with sufficient efficiency.

During the past two years, we have reorganised all manufacturing technologies and assemblies in accordance with these considerations.

The reorganisation of the entire system did not result in a deterioration of the quality level, as may be objectively demonstrated by means of product audit assessment graphs; in addition, it has been possible to cut down costs on quality assurance, on subsequent machining and on rejects and to achieve a very essential effect: We are now much more aware of the ins and outs of our manufacturing processes, and after having coordinated matters, the design engineer is given assurance that his drawings conform with the imperatives of manufacture.

Moreover, our quality assurance system has been granted the autorisation in accordance with AQAP 1, which corresponds to the most severe set of requirements made on a quality assurance system.

The most important byproduct obtained by our coordination studies is the fact that geometrical parameters of an advanced order, such as size, position or roughness, are no longer negligible in the case of highly rationalized manufacturing processes, but fall into the same orders of magnitude as the measurement tolerances themselves.

All illustrations by courtesy of Steyr-Daimler-Puch AG, Graz. The author is employed by this company. This paper was first published in German in Werkstatt und Betrieb 117 (1984) 3, p. 135.

Enter 139 on Reader Service Card or contact
Steyr-Daimler-Puch AG, POB 823, A-8011 Graz, Austria

Enter 140 on Reader Service Card