Best Clamping Method for Testing Gear after Heat Treatment Against Warpage

Rahul Parikh, Parag Gholawade, Rohan Ghorpade, Amol Pangare, Mr. Mukesh Chaudhari.
(student, student, student, student, guide)
Mechanical Engineering Dept.
KJCOEMR,
Pune, India

***Abstract*— Gear design engineers understand that heat treatments play a complex and vital role in both the ease of manufacturing and the performance of the gears. Today, many options exist for the heat treatment of gears. Proper selection and design of the heat treatment process can greatly affect performance, ease of manufacture, and economics of a component. The purpose of this paper is to get a best method for gear clamping in order to check any of its dimensions by studying variety of different processes and highlight some benefits and disadvantages of each. Gear goes through various processes in the heat treatment department which causes warpage in the gear which needs to be detected in advance further working on gear to avoid loss in time, money and eventually productivity loss. This warpage causes various geometrical errors in circularity, roundness and phase run out to name a few. This errors go undetected as there is no provision for testing the gears for above mentioned parameters. So as to take a pro-active measures to avoid these rejections there is a need to develop a best technique testing equipment. Initially paper goes through the basic method of GO-NOGO gauges. It discuss gauges in details and further its disadvantages in the present pace world. The second method studied in details is the Hydraulic/Pneumatic process for gear testing which proves to be a better method than the previous GO-NOGO in many ways. The best method used and studied is the hydro-pneumatic intensifier process. . The design was checked and validated for safety under the action of forces. The design of a fixture depends a lot on the designer's expertise and experience and hence no solution is optimal or near optimal for a given workpiece and therefore an attempt to find the best method is made considering various points using a pugh matrix six sigma tool.**

Keywords*— *Gear Clamping, Heat Treatment, Hydro-pneumatic

I. HEAT TREATMENT

Heat treatment is a critical and complex element in the manufacturing of gears that greatly impacts how each will perform in transmitting power or carrying motion to other components in an assembly. Heat treatments optimize the performance and extend the life of gears in service by altering their metallurgical and physical properties. These properties are determined by considering the gear's geometry, power transmission requirements, stresses at different points within a gear under load, load cycling rates, material type, mating part designs, and other operating conditions. Heat treatments improve physical properties such as surface hardness, which imparts wear resistance to prevent tooth and bearing surfaces from simply wearing out. Physical properties such as surface hardness, core hardness, case depth, ductility, strength, wear resistance and compressive stress profiles can vary greatly depending on the type of heat treatment applied. For any given type of heat treatment the results can be tailored by modifying process parameters such as heating source, temperatures, cycle times, atmospheres, quench media, and tempering cycles to meet specific application requirements.

Gear design engineers understand that heat treatments play a complex and vital role in both the ease of manufacturing and the performance of the gears they make. Today, many options exist for the heat treatment of gears. Proper selection and design of the heat treatment process can greatly affect performance, ease of manufacture, and economics of a component. Distortion is always a factor in heat treatment processes which can go unchecked until a proper method is devised to check the anomaly. This paper will focus on a variety of different methods and highlight some benefits and disadvantages of each.

II. GO-NO GO GAUGES:

Errors though inevitable mostly occur due to carelessness on the part of the operator concerned. As a machine operator much of the responsibility of gaging accuracy lies with him.

Fixed gaging tends to be economical for inspection tasks that require high throughput, and for production runs that involve many thousands of parts, and that last for months or years. Adjustable gaging tends to be appropriate for shorter production runs and for smaller shops in general. Similar issues apply when comparing "gaging" and "measuring." Gaging tends to be faster, both because it is less general-purpose in nature, and because the operator need observe only the last digit or two on a display, rather than count all of the units and decimals up to the present dimension. Because of its generally much shorter range, gaging can also be engineered for higher accuracy (resolution and repeatability) than measuring instruments. For anything resembling a production run, gaging is almost always required. But where single part features must be inspected, measuring devices tend to make more sense. In practice, most shops will find they need some of both types of devices.

A. DEMERITS OF GO- NO GO

- GAGING: REAL DIRT

Every machinist should at least nominally be aware that dirt can interfere with the ability to take accurate measurements. But the importance on the issue cannot be over-emphasized, and even a conscientious user can occasionally use a reminder.

- GAUGE: SQUEEZING MORE ACCURACY

All gauges are engineered to provide a specified level of accuracy under certain conditions. Before specifying a gauge, users must take stock of all the parameters of the inspection process.

How quickly must inspection be performed? Many gauges which are capable of high levels of accuracy require careful operation to generate reliable results. Others are more fool proof, and can generate good results more quickly, and with less reliance on operator skill.

Likewise with many other factors in the gaging situation, the ability to obtain specified accuracy from a gauge in a real inspection situation depends upon the prior satisfaction of many parameters, both explicit and assumed.

- GAUGE: CONTACTS- Contact size and shape are critical

In spite of their apparent simplicity, gauge contacts represent a source of many potential measurement errors. When the simple act of touching a part can change its dimension, it's important to understand the ramifications of contact selection and application.

The first consideration must be whether you actually touch the part. If the critical dimension is the low spot, it may be necessary to explore the part with the gauge.

- STAGING IT RIGHT

Some gaging applications call for inspecting a part for variation across a given feature, which calls for freedom of movement in at least one plane. Other applications call for measuring a series of parts at exactly the same location on the feature, time after time. In the first instance, checking the accuracy of the part and secondly checking the repeatability of the process where freedom of movement would tend to be an error.

- FIXTURES ARE A COMMON SOURCE OF GAGING ERROR

Fixture is also a common source of measurement errors. The fixture establishes the basic relationship between the measuring instrument (that is, a dial indicator) and the workpiece, so any error in the fixture inevitably shows up in the measurements. Many fixtures are designed as a variation of a C-frame shape and, as such, have a substantial cantilever that is subject to deflection. This problem is greatly reduced if the fixture is a solid, one-piece unit.

Most fixtures, however, consist of a minimum of three pieces: a base, a post, and an arm. These components must be fastened together with absolutely no play between them.

- CENTRAL INTELLIGENCE

Many factors influence the accuracy of hole diameter measurements. One of the fundamental requirements in bore gaging is that the gauge contacts be centered in the bore. Bore gauges that are not properly centered measure a chord of the circle, rather than its true diameter. Operator error is a common cause of poor centralization with rocking-type gauges, while wear or damage can affect the centralization of any gauge.

Gauge users should be prepared to calculate how far off the bore centerline a gauge may be without exceeding the specified centralization error. The allowable distance between the bore centerline and the contact centerline is called misalignment tolerance.

- BASICS NEED TO BE RIGHT:

After all, the fanciest electronics, computers and software won't deliver accurate results if good gaging practice is absent. And even occasionally all tend to forget old tricks. So a couple of the bedrock principles applied virtually to every precision measurement situation: proper gauge specification; and inspection, care and maintenance.

B. Inference: PERFECT GAGING IN AN IMPERFECT WORLD

It is certainly not news that, more and more, gauges are being forced out onto the shop floor. Tight-tolerance measurements that were once performed in a semi-clean room by a trained inspection technician are now being done right next to the machine, often by the machinist. To assure good gauge performance, there are a number of specifications and care issues which need to be addressed. The main problem in verification process is the propagation of uncertainties. With a correct expression of a virtual gauge, it is possible to avoid this propagation; indeed by using a virtual gauge manipulation, initial best-fitted surfaces are never altered. [6]

III. HYDRO-PNEUMATIC

The proposed hydro-pneumatic fixture to check the Total Indicator Reading (T.I.R) of the gear with respect to bore after heat treatment, checks for various geometrical parameters like phase run-out, circularity, cylindricity, concentricity etc.. Being hydro-pneumatic it gives an edge over other gear testing procedures.

The design is quite simple and only the method of clamping makes it distinct from other gear holding fixtures. The hydraulic and pneumatic combination saves lot of bulkiness to the apparatus and makes it compact for use. Moreover, it works efficiently with available pressure and eliminates any further arrangement of pumps, compressors etc. The Total Indicator Reading (T.I. R) is checked with the help of simple dial gauge which is mounted on the whole assembly.

The fixture is designed to check the T.I.R. as deviation in reading will indicate that any one or more geometrical parameters of gear are not in conformation with the required ones. The fixture is basically designed to recognize these geometrical distortions of the gear caused due

to heat treatment. Heat treatment of gears after their manufacturing resulted in scaling. This scaling was unavoidable in spite of various measures taken by the organization. There was no provision to check this distortion due to heat treatment and several geometrical errors it caused.

Subsequently, it resulted in increased rejection of gears by the quality department. As the effects due to heat treatment were inevitable it was decided to check the gears for various geometrical entities after heat treatment and then dispatch them further to the concerned department. Hence, it was required to develop a fixture to check the total indicator reading of the gear which will give an indirect manifestation of errors in heat treatment.

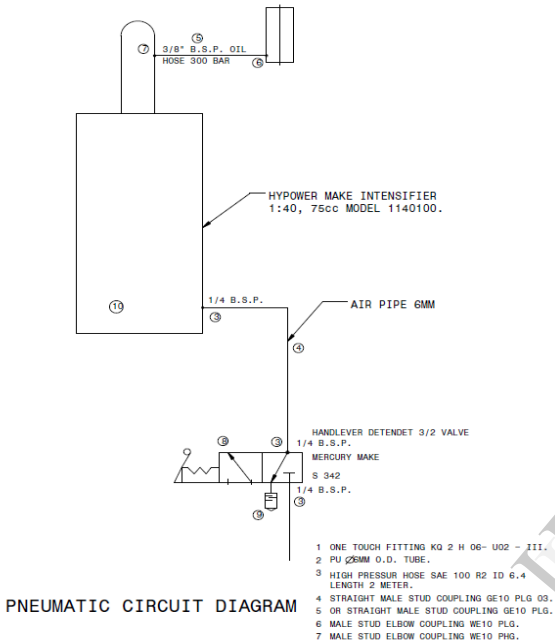

Fig 01: Hydro-Pneumatic Intensifier Circuit

The gear is placed concentric with the expansion sleeve. The figure shows the Hydro – Pneumatic intensifier circuit using intensifier and 3/2 spool operated DCV valve which is supplied with air under pressure which further intensifies the oil finally expanding the sleeve. Hence, the expansion sleeve expands and engauges with the gear making it clamp. The diagram below shows two expanding sleeves used to clamp two various types of gears. After the clamping the gear is rotated manually and the dial indicator placed above is used to check the dimensions of the gear such as concentricity, roundness, etc. making it a semi-automatic clamping and gear testing fixture. This method of checking the TIR is done after the heat treatment of the gear, so the rejection of gears at the end user can be avoided to save time, money and improve productivity.

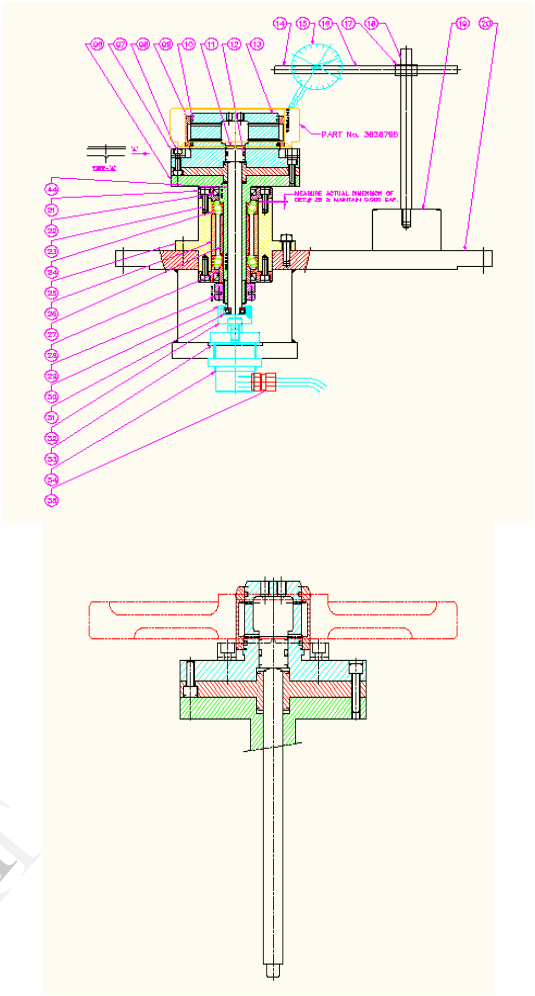

Fig 02: Hydro-Pneumatic Clamping using expanding sleeve

A. Pressure Intensifier Testing: Merits & Demerits

The pressure testing of containers using accurate pressure profiles is both complex and difficult to safely achieve. To date the majority of equipment on the market place uses air/gas pressure; which in the event of container failure can cause disastrous results.

Designed and built exclusively, the high pressure intensifier delivers fluid pressures at a single stroke. The intensifier is the ideal choice for pressure testing of cylinders, valves, gears, containers and vessels where pressure is of critical importance in the testing function and needs to be delivered with high levels of accuracy and stability.

- The intensifier delivers high accuracy pressure testing.
- Enabling fast testing of products.
- Intensifier is well developed avoiding errors.
- Reliability and Sustainability form a good advantage.
- Produces controlled test pressures in fluid.
- Constant Flow with no jetting or pulsing.
- Output pressure ≤ 700bar.

No Method can be perfect. We can always consider the best method relative to the other one. Some of the demerits of Pressure intensifier have been listed below.

Table 1. Problem and Guide to Hydro-Pneumatic

PROBLEM	GUIDE
Intensifier reciprocates but no fluid delivery (cylinder will not extend)	Outlet pressure is equal to the inlet pressure ratio (approximately 5:1)
Low fluid delivery (cylinder extends slowly)	Inadequate low pressure power source. A) Check inlet pressure. B) Contamination, check inlet port or intensifier (plugged inlet orifice)
Intensifier will not build to maximum pressure (no visible leakage)	Check low pressure power source
Intensifier builds pressure but will not hold system pressure	Check the hydraulic connections and other system components for leakage, including 3/2 valve
Intensifier will continue to run slowly even after desired pressure is reached.	1. Leaking components or system creep. 2. Defective 3/2 way valve
Overheating	1. Excessive inlet flow. 2. Excessive inlet pressure

IV. SIX SIGMA TOOL: PUGH MATRIX

Six Sigma is defined as an organized and systematic method for strategic process improvement and new product and service development that relies on statistical and scientific methods to make dramatic reductions in customer- defined defect rates. [3] One of the key elements of the Six Sigma strategy is the systematization of these methods and tools of quality improvement into one complex methodology [4].

The Pugh matrix is a tool used to facilitate a disciplined, team-based process for concept generation and selection. Several concepts are evaluated according to their strengths and weaknesses against a reference concept called the datum (base concept). The datum is the best current concept at each iteration of the matrix. The Pugh matrix allows us to:

1. Compare different concepts
2. Create strong alternative concepts from weaker concepts
3. Arrive at an optimum concept that may be a hybrid or variant of the best of other concepts

The Pugh matrix encourages comparison of several different concepts against a base concept, creating stronger concepts and eliminating weaker ones until an optimal concept finally is reached. Also, the Pugh matrix is useful because it does not require a great amount of quantitative data on the design concepts, which generally is not available at this point in the process. Therefore we have here used this tool to get through a best optimum method for gear clamping and testing. The pugh matrix analysis is as follows,

Table 2. Pugh Matrix Tool

Criteria	Go- No Go system	Hydro-Pneumatic System
Accuracy and Precision	-2	2
Input Supply	2	0
Sustainable	1	2
Inspection costs	1	-1
Inspection Time	1	0
Ease of use	-1	1
Part Cleanliness	0	0
Gaging environment	-2	1
Mobility	1	0
Manufacturing process	-1	-1
Cost of maintenance	0	-1
Cost	1	0
TOTAL	1	3

V. CONCLUSION.

As gear plays a important role in both the ease of manufacturing and the performance of the gears. As heat treatment being a must process for the gear to improve its performance cannot be neglected and the warpage is an unavoidable outcome which could be reduced to some extent but not totally overcome. Testing of these gears after heat treatment is a must and therefore getting through the best method for the same is really important. As we have studied the two of the most important methods and finally, the above pugh matrix tool shows that the intensifier is a better method in comparison. Various criterias are studied in order to get a hand on the best method so as to improve productivity by reducing time and cost.

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