FORGEABILITY OF 25%GRPOM (CELCON^{R}) TO PRODUCE SPUR GEAR UNDER HOT CONDITIONS THROUGH SLOW SPEED PRESS.

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ABSTRACT

This research studied forgeability of preheated billet of 25%GRPOM plastic through closed die forging technique using spur gear design. The type of deformation was discussed as well. This process had done after heating the billet and die assembly at 100^{o}C to achieve complete gear shape taking into consideration testing the product to insure no inside or outside defects with improvement in the mechanical properties. Cycle time to produce a complete shape was two minutes.

الخلاصة:

درس البحث قابلية العينة المسخنة مسبقا لمادة الاسيتل المقواة بنسبة (25%) الياف زجاجية على الكبس خلال عملية القالب المغلق باستخدام قالب ترس عدل . كما ناقشت نمط التشوهات على القطعة المشغولة. اجريت العملية بعد تسخين العينة و مجموعة القالب لدرجة (100 ^{o}م) لغرض انجاز ترس كامل الشكل اخذين بالاعتبار فحص المنتج من الداخل و الخارج لضمان خلوه من العيوب مع تحسن الخصائص الميكانيكية. استغرق وقت العملية لانتاج شكل كامل دقيقتين

KEY WORDS: (Forging , GRPOM, Recovery, Dwell time).

CLAIMS:

- Forgeability of 25%GRPOM (celcon^{R}) through closed die forging technique to produce spur gear at (100^{o} C) conditions
- Behavior of the polymer through forging action taking into consideration that typical forging process usually done at a temperature (5^{o}C) just below melting point (Kulkarni 1995). Melting temperature for it is about (166^{o}C).

INTRODUCTION

Polyoxmethylene always has been referred to as polyacetal resin. This polymer as an engineering material has been fabricated by forging process after being filled with 25%glass to get high stiffness. (GR POM) can be difficult cold forged (Wang & Lin 2007). It is almost fabricated after heating the billet and the tools to a temperature Just below softening point (KULKARNI 1995) to make it non-recoverable and ductile enough to reduce spring back phenomena and to achieve product with high strength and stiffness better than what injection molding process does (CRAWFOR1985).

In general a polymer can be either cold or warm formed. Solid phase forming (spa) indicates any of them (Wang & Lin 2007).

Press forming is to use a slow squeezing action of a press to transfer uniformly a great a mount of compressive force to the bulk of material (work piece) in three directions (COFFMAN1990). This process yields parts that have high strength to weight ratio thus is often used in the design of a particular applications where this property is of great demand (CRAWFOR 1985). Compressive force in such technique actually depends on the billet dimensions and the amount of deformation for the work piece which is forged below softening point. 25%glass reinforced acetal is a thermoplastic, ductile after preheating. Closed die forging technique mostly used when the design beyond injection molding technique capability such as ultra high molecular weight polymer, complex design geometry or higher strength and stiffness are wanted (COFFMAN 1990). The most powerful advantages of plastic gears may be the design opportunities they afford. Gear geometries overlooked by designers used to metal are often easy to mold in plastic, and they can reduce drive size, weight, and cost, in addition to their resistance to solvents and alkalizes and service temperature closed to $100C^0$. GRPOM has excellent clarity, dimension stability which prevents shrinkage (COFFMAN 1990).

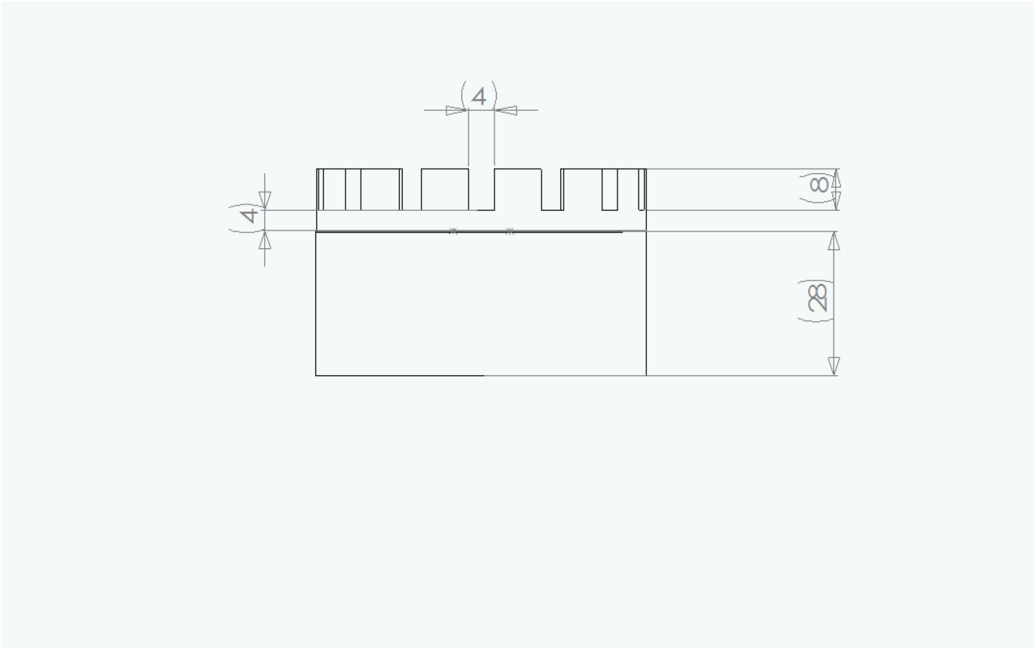
APPLICATIONS:

Spur plastic gears are usually used after machining for:

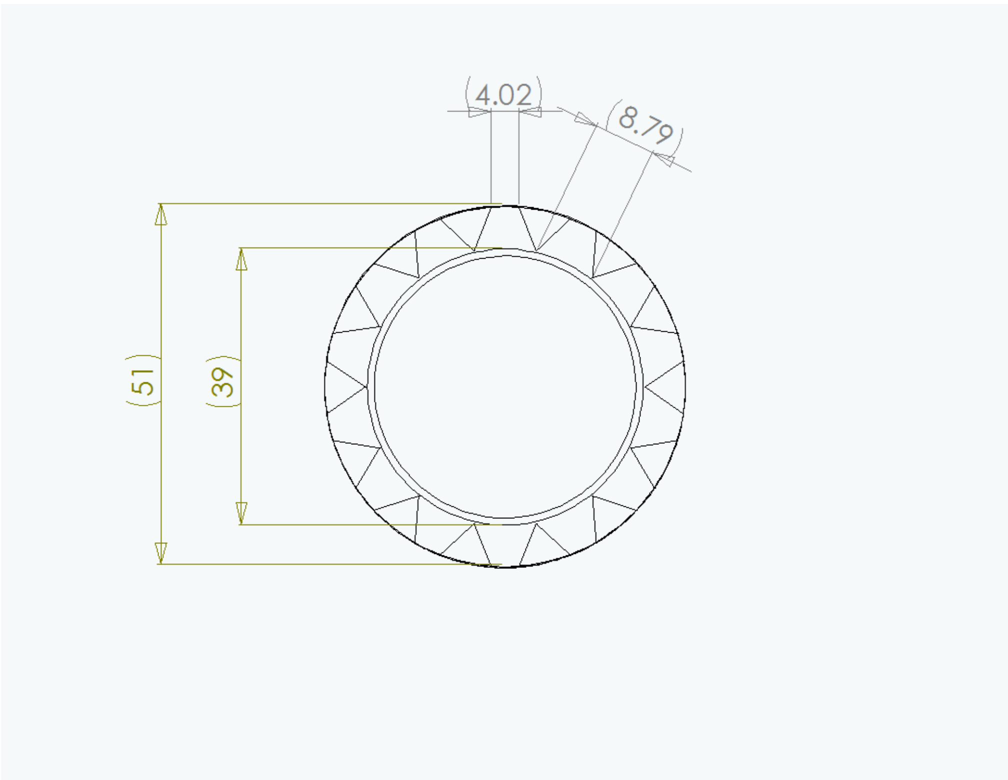
- Low speed applications.
- Power transmissions.
- Film winding.

Examples of spur GRPOM gear uses:

- Windup alarm clock.
- Washing machine.
- Electric screw driver.
- Oscillating sprinkler.



FRONT VIEW



TOP VIEW

Fig.1: DIE DESIGN (in mm)

EXPERIMENTAL PROCEDURES: (Fig.2, Fig.3)

- The process was done using slow speed press.
- The billet was a solid rod of GRPOM with cross section area of (25mm); length was (65mm).
- Number of samples (billets) used =20
- The die of gear had out side diameter equal (51mm) and inside equal (39mm). Tooth number = 14.
- A load cell consisted of strain gauge was used to transmit the compressive load to the strain recorder then to an amplifier. The amplifier then connected to Bryan X-Y plotter to get graphs of load against displacement, then to be converted later to (stress-(strain) curves describing the style of flow done by yielding action.

Billet specifications:
Tensile strength = 65Mpa
Hardness (R.W) = 80(scale M)
Melting point = 166^{o}C

The billet was put into the die and whole assembly was placed in an oven over night. The temperature was adjusted to 100 ^{o}C . The strain gauge was insulated from the hot punch by the use of an asbestos slab to prevent unwanted effect of strain gauge due to heating. After putting the die assembly below the machine punch, switching on, then The press head was brought down and the forging carried out. When the pen of the plotter started to move vertically, load was again held constant at that particular point. The process took two minutes to achieve complete plastic gear.(see Fig.2).

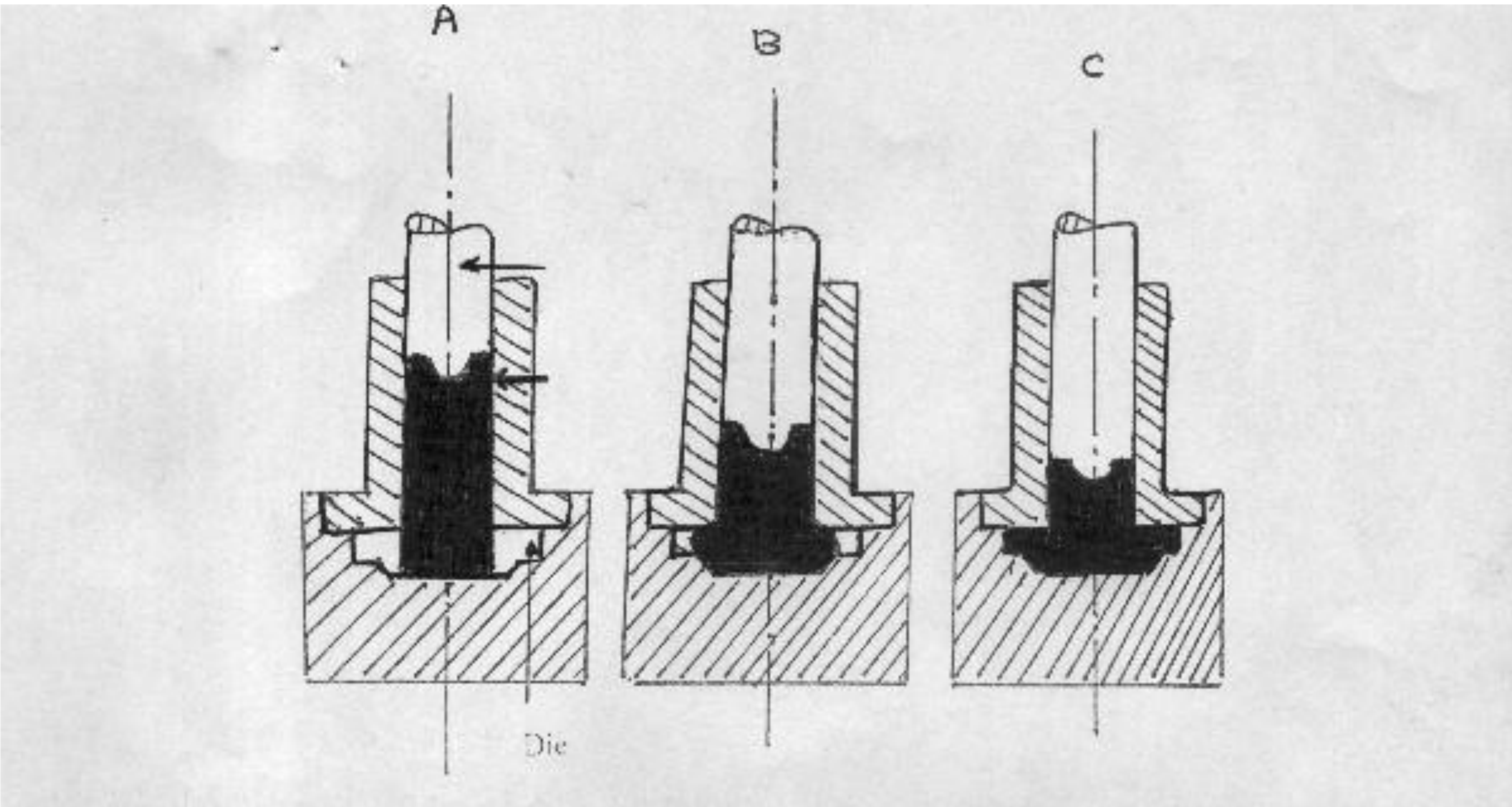


Fig.2- stages of gear formation:

A. The punch is ready to forge the billet.
B. The pressure increased gradually to (80)Mpa to fill the cavity of the die except corners of tooth.
PUNCH **C. The shape of spur gear was completed under 110Mpa**.

RESULS & DISCUSSION:

Product test:

The final result was a complete plastic gear produced through closed die forging process in two minutes for each sample(Fig.4), taking into consideration no inside or

outside defects, but a smooth, shinny plastic gear was achieved with improvement in the mechanical properties, but in the direction of loading.
Tensile strength = 140Mpa (in one direction).
Tensile modulus = 4.2Gpa (in one direction).
.Hardness (R.W) = 87 (scale M)
Stress at 1% strain = 10Mpa

Yield stress at 3.5 strain = 56Mpa
Forging pressure: this was the stress required to form the gear shape due to punch action through the forging process indicated by stress-strain curve below.
1^{st} stage = 80Mpa
2^{nd} stage = 110Mpa
Dimensions stability were within 1% in three dimensions achieved after dwell time equal to 50second to reduce recovery action, in addition to eight hours outside the die to insure complete stability of dimensions that should not exceed 1%.

Dimensions of rod specimen in mm prepared for tensile test under designation of DIN 638 (see Fig.3)

Table.1

Nominal Diameter	Length of Radial Section	Standard Length	Length of the Jaws	Groove Length
22.2	51.5	400	89	57

Notes :

- the diameter of the machined portion (a straight section groove) was 60% of the original length.
- the length of the machined portion was 57.0 mm.
- test specimen was machined for preparation.
- five specimens were tested at room temperature, test time for each was three minutes.
- the grips were tightened in proper way to prevent slippage of the specimen.
- the tensile strength was calculated by dividing the maximum load in Newton by the original minimum cross-sectional area of the specimen in square meters expressing the result in Pascal.

- the modulus was calculated by extending the initial linear portion of the load-extension curve and dividing the difference in stress corresponding to any segment of section on this straight line by the corresponding difference in strain.
- the specimens were considered under type Rigid and Simi rigid III rods that speed of test is 5 mm/min .

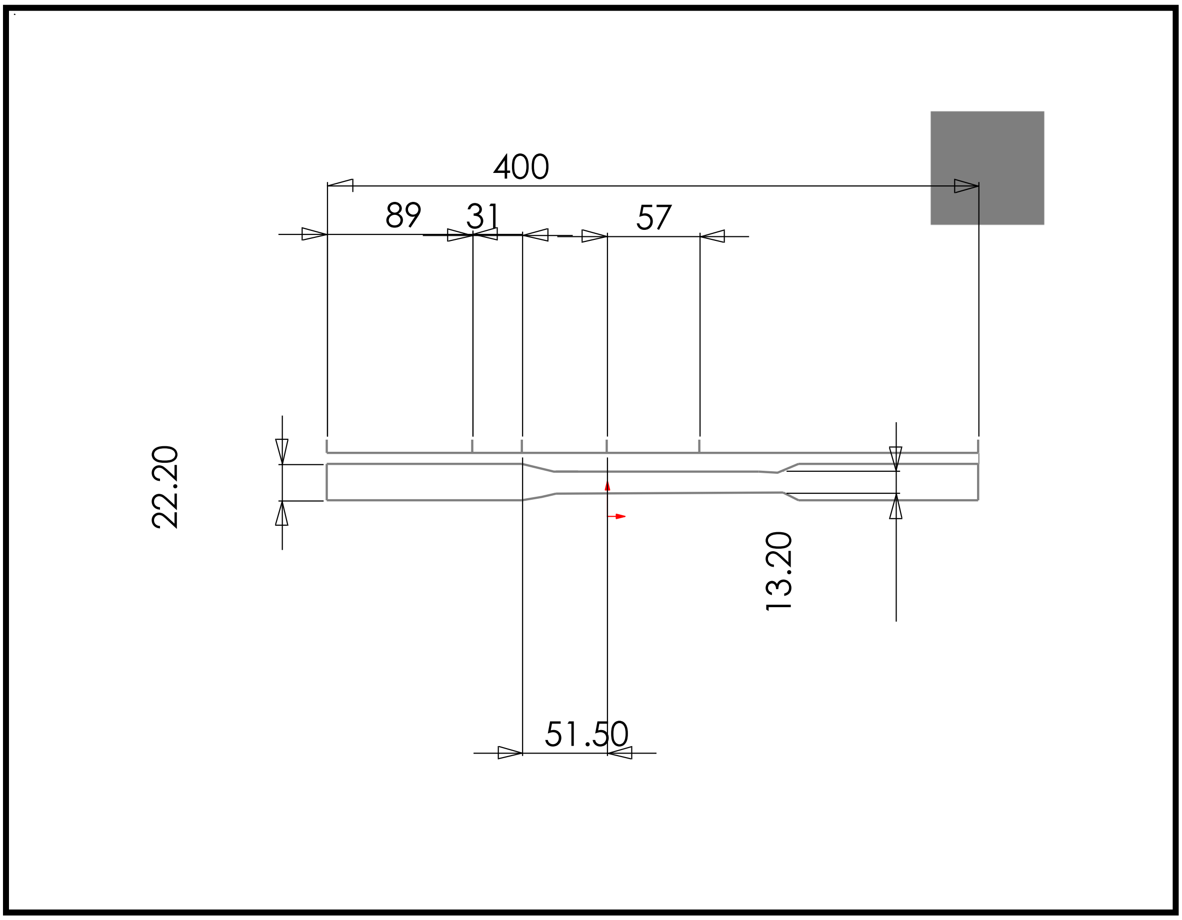
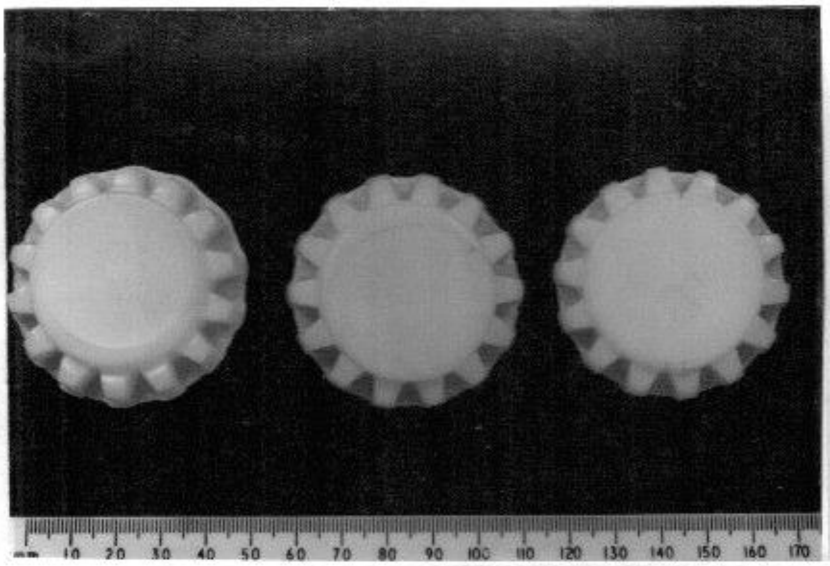
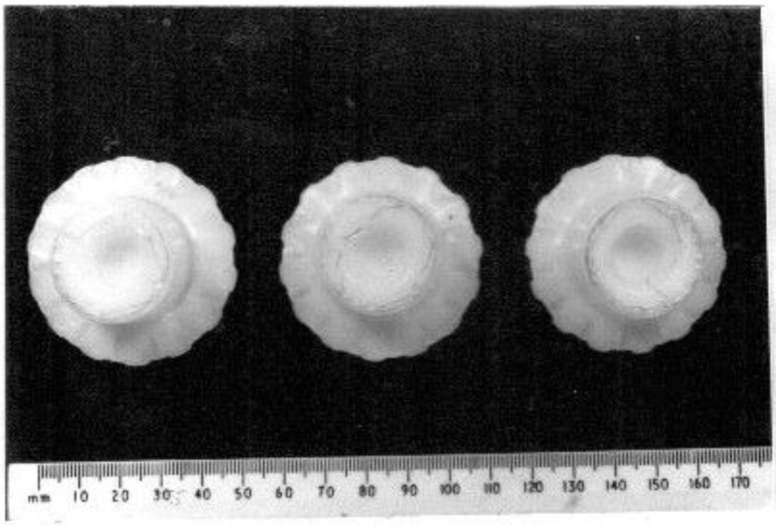


Fig.3 : Tensile test specimen (dimensions are in table.3)



(1) (2) (3)

FIG. 4.3-A BOTTOM VIEW



(1) (2) (3)

FIG. 4.3-B TOP VIEW

Fig.4: a smooth shinny plastic spur gear product -before machining- using glass reinforced acetal (celcon^R) billet heated at 100^o C .

Load – Displacement curves behavior:

According to Fig.5, two types of deformation behavior can be recognized

- Elastic range which is represented by (OA), that 22 KN was the load applied to achieve reduction in height equal to 1.25 mm.

- Viscous non-linear plastic deformation range that occurred because this polymer behaved as viscous element and non-linear simultaneously. These behaviors represented by:
- (AB) which is the deformation occurred due to increased load from 22 KN (yield point) to 45 KN that was the load required to achieve displacement equal to 11.75mm at the plastic zoon.
- 2. (BC) which is the deformation occurred due to increased load from 45KN to 80KN to fill the whole cavity of gear die. For this section, a reduction in height equal to 3mm was achieved. Hence a total reduction in height through whole process was 16.5mm.

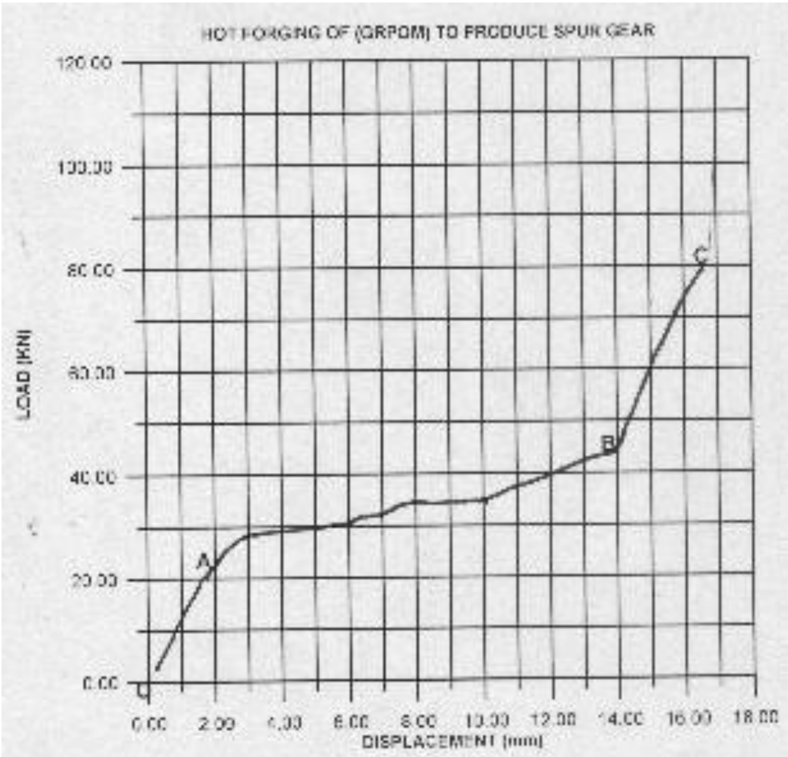


Fig.5: load – displacement curve

Stress-Strain relation:

From Fig.6, the style of deformation indicates the pressure required through each step of gear formation that allowed strain to be represented according to the viscoelastic manner of the plastic material causing the plastic deformation to follow anon-linear strain path supposed to be horizontal straight line, but it is not, because the behavior of the polymer mentioned above (J.C.Choi 1999).

- Yielding action of the polymer was starting at applied pressure of 56Mpa, then increased to 70Mpa to achieve a viscous non-linear part of 12% strain.
- A second part of strain - which is approached 17% achieved due to constant pressure of 80Mpa. At this stage, the polymer filled gear die except tooth.
- The pressure, then increased rapidly approaching 110Mpa until strain held constant and whole gear would be formed after two minutes time.

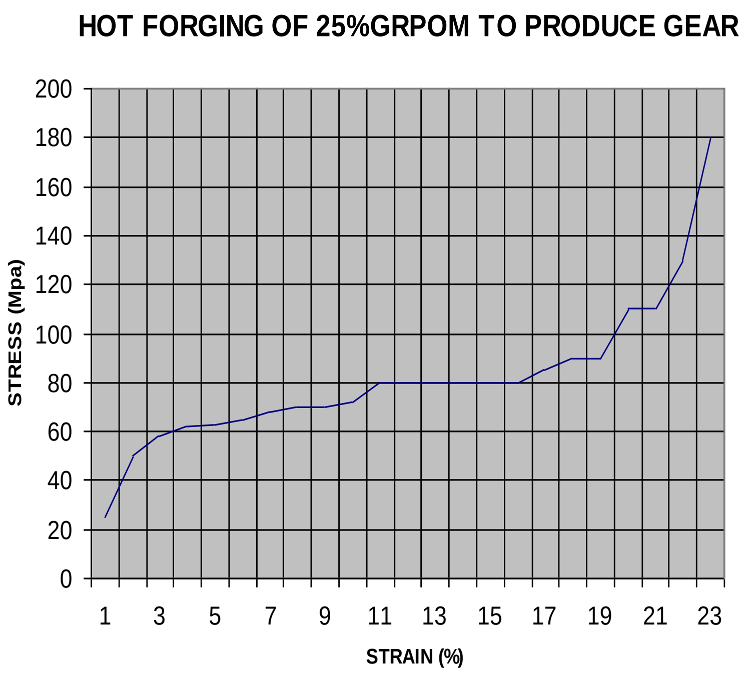


Fig.6: stress – strain curve

CONCLUSIONS:

- The plastic material 25%GRPOM was capable of being used to produce gear through closed die forging technique after heating the billet & tools at (100^{o}C).
- Cycle time for the same work done at typical heating is 50 second (Kulkarni 1995), while it took 120second (including dwell time) to produce a complete gear.
- Excessive pressure were needed to fill the corners of the gear die with polymer to achieve complete tooth filling. That flange shape of the die required a stress of 80Mpa, while the tooth formation required 110Mpa.
- The material showed viscoelastic behavior as it indicated in fig.5.
- Mechanical properties improved more as long as heating far away below softening point, but with too long cycle time to prevent possibility of recovery, So, care should be taken in choosing the right polymer.

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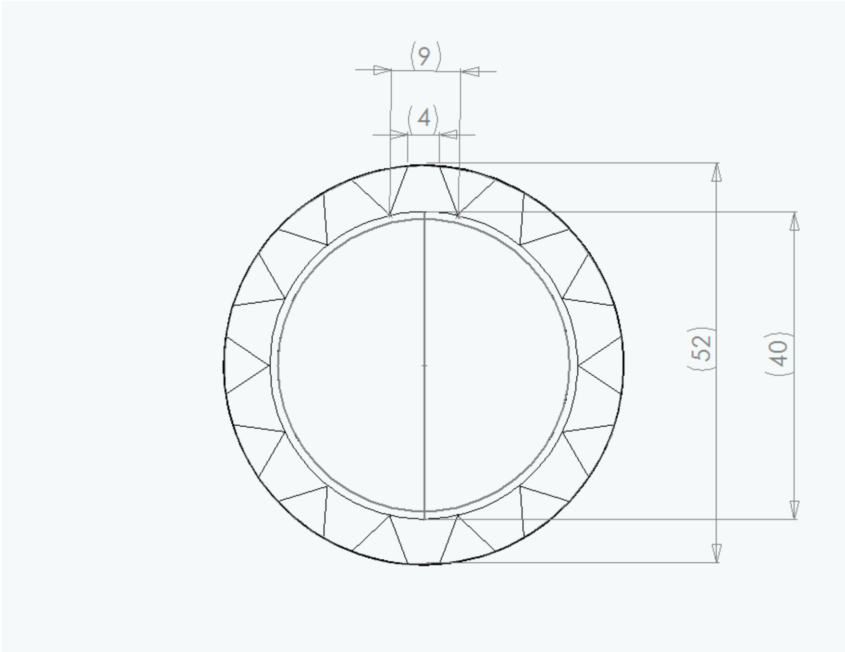
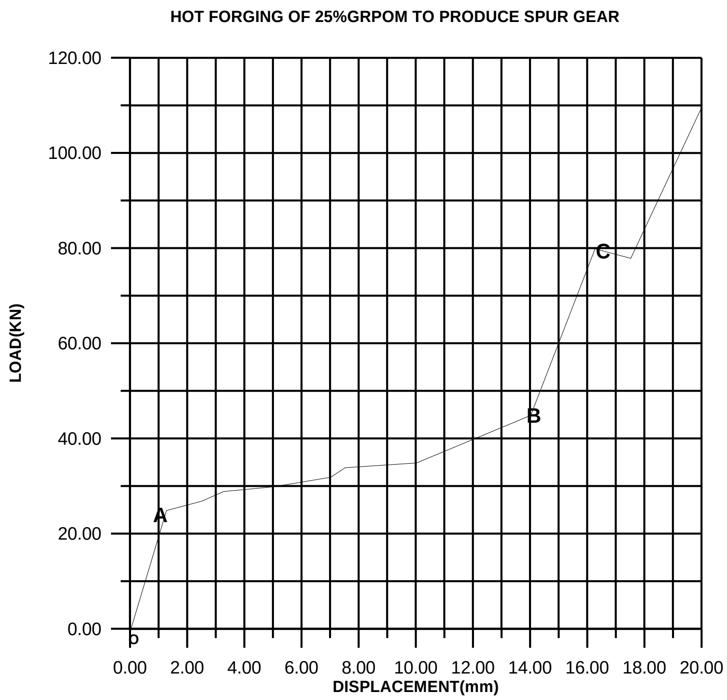

(9)
(4)
(52)
(40)


HOT FORGING OF 25%GRPOM TO PRODUCE SPUR GEAR
LOAD(KN)
DISPLACEMENT(mm)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
A
B
C
O