$$h(t,Z) = \frac{\beta}{\eta}\left(\frac{t}{\eta}\right)^{\beta-1} e^{\Upsilon f_x} = \frac{5.99}{7406}\left(\frac{t}{7406}\right)^{4.99} e^{0.022\, f_x} \qquad (3)$$

Kolmogorov-Smirnov test (K-S test) is used to evaluate the model fit. The test shows that the PHM offers a good modeling for the data .The summary of goodness of fit test is automatically produced by EXAKT as in table III.

TABLE III. SUMMARY OF GOODNESS OF FIT TEST RESULTS

Test	Observed value	P-value	PHM Fits Data
Kolmogorov-Smirnov	**0.174794**	**0.889842**	**Not rejected**

The statistical model shows that the effect of radial force is higher than the effect of cutting force and the feed force, on the progressive flank tool wear. In Fig. 2, the experimental data of tools 1 to 5 is plotted. The graphs show that radial force is intimately related to progressive flank and carries direct information about the failure process. This is the same conclusion showed by the results of Huang and Liang [12].

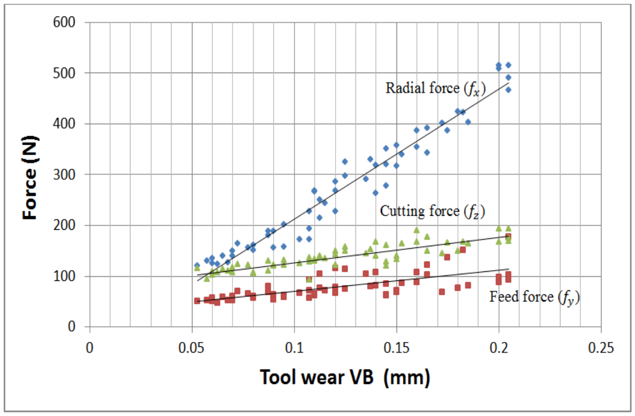

Fig. 2. Cutting forces with the progress of flank wear v = 40m/min f = 0.15 mm/rev

IV. OPTIMIZATION TECHNIQUES

A. *Cost optimization*

Expected cost/unit cycle time is written as:

$$\phi(T_d) = \frac{C_p\, P(T_d<T) + C_f\, P(T_d \geq T)}{W(d)} \qquad (4)$$

Where T is the failure time, T_d is the preventive replacement time, Cf is the failure replacement cost, and Cp is the preventive replacement cost. The optimal cost is achieved when $\phi(T_d)$ is minimum where T_d^* is the optimal time to replace. $P(T_d < T)$ is the probability of preventive replacement, $P(T_d \geq T)$ is the probability of failure replacement, and $W(d) = E(min\{T_d, T\})$ is the expected cycle length.

B. *4.2 Availability optimization*

$$A(T_d) = \frac{uptime}{uptime+downtime} = \frac{W(d)}{W(d)+T_p\, P(T_d<T)+T_f\, P(T_d\geq T)} \qquad (5)$$

Availability (A) is the percentage of time that cutting tool is available for machining. The optimal availability is achieved when $A(T_d)$ is maximum, where T_d^* is the optimal time to replacement, T_p is the preventive replacement time, and T_f is the failure replacement time.